A Revision of the Gibbaeinae (Mesembryanthemaceae)

by

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C O N T E N T S

ABSTRACT

Of the fourteen species of Gibbaeum recognised in this work, one, G. austricolum is new. A new combination, G. pubescens (Lettsom ex Haw.) N.E.Br. subsp. shandii (N.E.Br.) Glen, is made at the subspecific level. Three monospecific genera, Antegibbaeum, Didymaotus and Muiria, and two intergeneric hybrids, X Muiriogibbaeum and X Gibbaeophyllum, the latter here described for the first time, are recognised.

A field study was made over the entire distribution range of the subtribe. Further studies were made of the vegetative, flower and fruit morphology, cuticular structure and seed and pollen morphology of the group. A numerical-taxonomic treatment of date gathered from these studies was made.

Keys for field and herbarium use, as well as a polyclave, are provided. Various features of the cytology, habitat preferences, conservation status and possible evolution of the group are noted.

2. INTRODUCTION

Prior to this study, the most recent revision of the genus Gibbaeum was that of Nel (1953), whose work did not include the related genera Didymaotus and Muiria. Nel's work was unfinished at the time of his death in 1950, so that his exact intentions with regard to one or two taxa remain obscure (Jordaan in Nel, 1953:9). The results of this revision were criticised by Bolus (1958a) and rejected by Jacobsen (1960, 1970). Furthermore, the assignment of names to specimens in the Bolus Herbarium, which has more specimens in the group than any other herbarium seen by the present author, follows neither Nel's nor Jacobsen's systems.

It seems desirable, therefore, to undertake a revision of the group using as many different approaches and characters as possible, to determine true generic and specific limits, as far as this is possible. Another direction of study which appeared desirable was to provide keys or other systems allowing the most rapid and positive possible identification of the scantiest possible material.

Especially in the highly succulent Mesembryanthemaceae a study such as this is fraught with problems that are not experienced by taxonomists working on nonsucculent plants.

The first of these is the relative dearth of classical characters for study. For example, the highly succulent and modified leaves in this group (Gibbaeinae)

usually have no margins, and are opposite throughout. Another example would be the genus Lithops, in which the surface carrying the information most used in species delimitation is morphologically a leaf-apex. Likewise, most organs of the flower in this family occur in large and variable numbers, and the ranges of variation between taxa tend to overlap the often larger ranges of variation within taxa.

Secondly, the literature of Mesembryanthemaceae is widely scattered in a large number of journals, many of which are now or were horticultural periodicals. Furthermore, much of the 'early' literature of the 1920's - 1930's can only be found in South Africa, in private collections or in former private collections deposited in libraries but not yet catalogued.

Finally, the relatively few herbarium specimens in the group are often poor. These were extensively supplemented by my own collections.

Dried specimens of succulent plants bear little resemblance to live plants, almost by definition. Much of the ability to identify live plants in the field is based on the recognition of three-dimensional shape and colour. Pressed specimens of Mesembryanthemaceae tend to be uniform in colour and two-dimensional, with the third dimension being represented erratically. The number of herbarium specimens of Gibbaeinae available at the beginning of the study with both flower and fruit was significantly smaller than the number with neither.

2.1 History of the genus Gibbaeum and its close allies

It is impossible to say exactly when and where the first Gibbaeum was collected. However, one may deduce the species and, roughly, its locality.

Haworth published the first descriptions of Gibbaeums in 1795. At that time, he included them all in the Linnaean genus Mesembryanthemum, which at that time contained some 155 species. He described M. nuciforme (now G. nuciforme) in his section Subaphylla, which also contained a Conophytum and a Monilaria. The other four species that he described, he placed in his section Subacaulia foliosa, which contained 31 species now placed in such diverse genera as Argyroderma, Dactylopsis, Cylindrophyllum, Acrodon, Cephalophyllum, Cheiridopsis, Machairophyllum, Carruanthus, Faucaria, Stomatium, Rhombophyllum, Glottiphyllum and Lampranthus.

Haworth (1794) notes that at that time the best collection of "fig-marygolds" in England was the King's at Kew. He described many new species from plants he saw growing there. It is thought that some of these plants survived until the first winter of fuel-rationing in the Second World war.

The second edition of the Hortus Kewensis (Aiton, 1811) lists all species of plants growing at Kew at that time, together with the date and agent of their first introduction. All four Gibbaeums described by Haworth are listed; three of them were introduced by Francis Masson, one (G. nuciforme) "about 1790", the

others (G. gibbosum, there called M. perviride, and G. pubescens) in 1792. The last, G. gibbosum (M. gibbosum of Haworth) was introduced "before 1780", and came from the garden of one John Fothergill, M.D. (Aiton; Lettsom, 1781).

In his catalogue of the plants in Fothergill's garden at the time of his death, Lettsom (1781) uses two names which are currently associated with species of Gibbaeum, namely M. gibbosum and M. pubescens. If one examines the itineraries of collectors at the Cape during this period (between 1753 - there are no Gibbaeum species in Linnaeus' Species Plantarum - and 1780), and discounts non-British collectors, there is only one possible conclusion, that the first specimens of Gibbaeum were collected by Francis Masson during his first residence at the Cape (1772 - 1775).

Masson (1776) records the itineraries of three journeys he undertook to the interior. The first of these was to Swellendam via Paarl, Stellenbosch and Sir Lowry's Pass, and lasted about six weeks. It did not take him anywhere near the localities of the Gibbaeums he presumably collected.

His second expedition was to the Sundays River in the Eastern Cape, returning via the Little Karoo. He records that on the 3rd January, 1774, he and his party crossed the Great Thorney River, and he and Thunberg, then being lost, covered a considerable amount of ground before regaining the rest of the party. In view of the fact that at the time he was crossing the western

tributaries of the Gouritz River, his "Great Thorney River" is most probably the Doorn River, which flows past Gibbaeum pubescens localities at Warmwaterberg and Lemoenshoek. It therefore seems likely that Gibbaeum pubescens was first collected at Warmwaterberg or Lemoenshoek, between the 3rd and the 14th of January, 1774.

Masson was joined by Thunberg on his third expedition, as he had been on his second. This time, they went northwards, as far as the Van Rhynsdorp Karoo. They returned via the Tanqua Karoo and Karoo Poort (i.e., they crossed the Ceres Karoo as well). They arrived at Verkeerde Vlei, near where the road to Ceres branches off from the present N9, a few kilometres south-west of Touw's River, on 11th December, 1774. They stayed in this area for three days. During these three days there would have been ample time to visit the Gibbaeum gibbosum locality at Hartebeeste Kraal, about 8 km. to the south-east. In fact, Masson could have collected G. gibbosum at any time between the 8th and the 14th December, 1774, as he was at the north-western end of its range at that time.

Masson returned to the Cape in 1785, and stayed for ten years. During this time he made various expeditions to the interior, despite instructions from Sir Joseph Banks to stay close to Cape Town. (Britten, 1884; Karsten, 1959). In the course of these expeditions he re-collected G. gibbosum and G. pubescens, and collected G. nuciforme for the first time. Haworth named the second

collection of G. gibbosum, M. perviride. It is not possible to pinpoint the locality of the original collection of G. nuciforme: Masson left no record of where he found it, and it grows close to both of the other species collected by him.

After Haworth died in 1833, the genus Gibbaeum was neglected until Sonder revised the Aizoaceae for Flora Capensis (Sonder, 1863).

By the turn of the century, this group of plants had acquired a reputation for being difficult to cultivate, but no new species had been described since Haworth's day. Indeed, some had disappeared from cultivation in Europe (Berger, 1908).

The modern phase of taxonomy of the Mesembryanthemaceae began in the early 1920's, with the recognition of many new genera by N. E. Brown, and a "race" between him, G. Schwantes and L. Bolus, in the describing of the new species that were being discovered all over the Karoo and Namaqualand, by collectors too numerous to mention. Often the same species was described as new by more than one author, but this is not as much the case in Gibbaeum as in other larger genera.

The genus was recognised as such by N. E. Brown in 1922, with five species. By 1939 this total had risen to over thirty.

Nel was busy with a revision of the genus Gibbaeum when he died in 1950. This was completed by Jordaan and published in 1953 (Nel, 1953). Seventeen species were recognised in that work, but no specimens

were cited. An extensive search both at Stellenbosch and Cape Town revealed no more than two specimens that were definitely collected by Nel.

L. Bolus did not recognise many of the changes made by Nel, and resuscitated the genera Antegibbaeum and Imitaria, which Nel had included in Gibbaeum (Bolus, 1958a). In 1960, the number of accepted species was 21 (Jacobsen, 1960). In the present work, this is reduced to fifteen and a subspecies, plus three species in the genera Antegibbaeum, Muiria, and Didymaotus.

The cytology of most species of Gibbaeum has been studied by Wulff (1944) and De Vos (1947, 1951).

3. METHODS AND MATERIALS

3.1 Light Microscopy

The method of Stace (1965) for macerating, staining and preparing permanent mounts of leaf cuticles was used. Glass dissecting needles were found to be necessary for transferring the cuticles from the watch-glasses in which they were macerated to microscope slides. It was found that the cuticles adhered to steel needles, and could not be flattened satisfactorily.

Photomicrographs were taken of each section, and measurements made on the resulting prints. If a scale is photographed on the same film at the same magnification as the specimens, the effect of distortions and shrinkage during processing will be eliminated. However, the negatives may be made on film with a dimensionally stable base if desired (Anonymous, 1969). The extent of shrinkage of the prints is calculated from readily available data (Hornung, 1971).

3.2 Scanning Electron Microscopy

Scanning electron microscopical (SEM) techniques were used to examine seeds and pollen grains of all available species of Gibbaeum, and the epidermis of Didymaotus lapidiformis. It was not possible to examine the epidermis of D. lapidiformis as outlined in section 3.1, due to the large amounts of surface wax, which completely obscured any underlying structure.

Although Gibbaeum, like most genera of the Mesembryanthemaceae, has hygrochastic capsules, it was necessary to break open the capsules as the seeds were to be prepared for scanning electron microscopical

examinati.n immediately. This eliminated a long drying step, but nonetheless a few seeds (about one per thousand) exploded in the course of preparation and viewing.

Two methods were used for preparing the dry seeds for viewing. In the first, they were attached to a stub with silver paint, which was thinned with alcohol when necessary. The seeds were coated with silver before viewing, in order to make them electrically conductive.

In the second method, seeds were attached to the stub with a small piece of double-sided adhesive tape. This was ringed with "Dag" and coated with silver as above. This is essentially the method used by Ridgway and Skvarla (1969) to study pollen. As the adhesive tape is an electrical insulator, the combination of seed, tape and stub is a primitive condensor. That is, it encourages the specimen to accumulate an electrical charge. In order for scanning electron microscopical examination to be possible, a path must be provided for the charge to leak to earth at least as fast as it accumulates. The function of the "Dag" (described by the makers as a conductive colloidal suspension of graphite) is to provide such a path from the surface of the tape to the stub, which is earthed.

Results from the two methods were indistinguishable provided that the energy of the electron beam did not exceed 5 kV for the adhesive-tape specimens. The others were examined with a 10 kV beam.

A minor modification of the method of Ridgway and Skvarla was used to examine the pollen from herbarium specimens. The tape was ringed with silver paint and

lightly coated with silver before the pollen was mounted on it. This gave a marked improvement in conductivity. As the silver layer is very thin - less than a micron thick - the adhesive properties of the tape are unimpared.

When necessary, all specimens were stored in a desiccator over calcium chloride, between preparation and viewing.

As the magnification of photographs taken with the SEM is accurately predetermined, measurements can be made on prints of known size and converted rapidly to allow for the magnification factor. In the case of the instrument used, a square print 10,5 cm. on a side, made from the whole negative, has the magnification indicated on the instrument at the time the negative was made.

3.3 Numerical techniques

3.3.1 Group forming

A numerical system was desired to organise copious data from all parts of the plant, minimising subjective bias in the results. The desired result was a phenogram that could be used in the setting-up of taxa within the group.

In addition to desirable logical properties, it was preferred that the system chosen should either be already set up on the available computer or be capable of being set up with a minimum of effort, as this would allow one to concentrate on data capture rather than programming.

One finds that one's choice of methods is restricted to those that can handle the classes of data (binary, multistate, modal) that are available in the study at hand. In this study, it was planned to use all three classes (see appendix 4 for definitions), and this considerably reduced the field from which a choice could be made, as many systems appear to be designed for binary characters only. Before choosing from this reduced field, it was further necessary to consider the problem of information distortion (Hall, 1969a). Only Hall's (1967a,b, 1969b) relative homogeneity and heterogeneity functions were specifically set up to avoid this kind of distortion. The BOLAID package, which uses these functions, (Hall, 1973) was developed and available on the U.C.T. computer. Therefore, it had the double advantage that not only was re-programming not necessary, but also the developer of the system could be contacted easily in case of difficulties.

While the present study was in progress, the BOLAID package was expanded by the addition of a module to extract pure size characters (Hall, unpubl.), using Hall's (1969c) algorithm. The effect of the use of this module on the data is discussed in section 4.1.

A number of group-forming runs were done, at least one (two when the size-extracting module was added) as each character suite became available. Sizes of runs varied between six character strings and six OTU's, and 131 character strings and 38 OTU's. Run-times varied between a few seconds and three minutes (of computer time).

The characters used are grouped by suites in tables 3.1 - 3.4. Maximum-and-minimum character strings, and maximum-mean-minimum string sets were grouped into two- and three-string properties, as detailed in appendices 2 and 5. The values found for each character for each OTU will be found in appendix 2.

Scored characters were taken as being over a large, indefinite sample, namely, all plants that the author had assigned to the OTU in question. Measured characters were means, minima and maxima or all three values of between ten and 25 individuals, except where fewer were available. Frequencies were taken over a minimum of 150 items.

Measured characters were entered into the data matrix in tenths of a unit ($m \times 10^{-4}$ or $m \times 10^{-7}$), except for clump size and flower diameter which were entered as centimetres and millimetres respectively. This was done because the BOLAID package is only designed to read integer numbers.

Characters that were self-evidently semi-correlated, e.g. nos. 7 to 9, were collectively deweighted to give the effect of a smaller, whole number of properties. This smaller number was one except in the case of the flowering-time characters, where it was three. Individual frequency modulation was applied to the flowering-time characters to suppress the large similarities that would otherwise have resulted from the many zero's (no flowering for that OTU in that month).

3.3.2 Key-forming and data banking

Currently-available mechanised identification systems have been reviewed very ably by Pankhurst (1974). The packages of Hall (1973), Morse (1974) and Pankhurst (1971) were, to a greater or lesser extent, available to this study.

Attempts were made to form keys using the key-forming module of BOLAID (Hall, 1973), and MSU (Morse, 1974). Due to difficulties encountered with both of these systems, the keys presented in section 5 were produced manually using the basic MSU algorithm on a data file in the MSU general format (Morse, Peters and Hamel, 1971). This file will be found in appendix 3. It can be used as a polyclave, as detailed in section 5.1.

At the start of this study, it was considered necessary to be able to determine which alleged taxa would be found at any particular place, and when they would be flowering or fruiting. It was found that Hall's (1972a,b) BOLIR system would be able to provide answers to this kind of question, as well as a checklist of

material seen. In the course of writing the taxonomy section of this work, it was found that the standardised list of specimens produced by the editing module was of such great usefulness in organising lists of specimens seen by taxa, as to offset the disadvantage of not being able to obtain such lists automatically, due to a breakdown in the computing system. This general editing list, with all its typographical and other errors was also found to be very useful on a number of other occasions.

Data banking systems can be divided into two groups: those that are supplied by the manufacturers for a particular computer system, and those of independent origin. Examples of the former are IBM's GIS (Krauss, 1973) and ICL's FIND-2 (Greene, 1972). Examples of the latter, other than BOLIR, are the Smithsonian Institution's SELGEM (Creighton et al., 1972), the University of Colorado's TAXIR (Brill, 1971) and Cambridge University's GOS (described by Crovello and MacDonald, 1970).

In principle, at least, it is not possible to use the former group on a machine not of the kind for which it was designed, while the ideal member of the other group should be easily transferable from one computer to another.

All members of the second group have both advantages and disadvantages. One disadvantage common to all systems not available to the user in an already-active form, is the vast amount of effort neededto start such a system (Kreger and Nathanson, 1971). If an IR system were not already functioning, it would not have been possible to justify trying to construct one

for the present 'once-only' study (Shetler, 1974). For this reason, further consideration of the relative merits and demerits of one or another system is irrelevant to the present study.

Table 1 Microscopical characters used.

string number	character number	Character description	
2	2	stomatal ratio	
3	3.1	minimum length of smaller cells	
4	3.2	maximum length of smaller cells	
5	4.1	minimum length of larger cells	where there are distinctly larger and smaller cells
6	4.2	maximum length of larger cells	
7	5	stomatal length	
8	6	guard cell length	
9	7	guard cell width	
10	8	cells per trichome	
11	9	subsidiary cells per stoma	
12	10	trichome frequency	
13	11	wall undulation	
14	12	wall sculpturing	
15	13	trichome branching	
16	14	trichome branch length	
17	15	trichome curl	
18	16.1	minimum chromosome number	
19	16.2	maximum chromosome number	
86	63	seed hue	
87	64	seed colour-saturation	
88	65.1	minimum seed length	
89	65.2	mean seed length	
90	65.3	maximum seed length	
91	66	seed length/width	
92	67	seed length/depth	
93	68	seed width/depth	
94	69.1	minimum length of funicle	as % of total seed length
95	69.2	mean length of funicle	
96	69.3	maximum length of funicle	
97	70	pattern form, centre surface	
98	71	pattern form, funicle surface	

string number	character number	Character description
99	72	pattern major axis length, centre surface
100	73	pattern major axis length, funicle surface
101	74	pattern minor axis length, centre surface
102	75	pattern minor axis length, funicle surface
103	76	pattern boundary line irregularity, centre surface
104	77	pattern boundary line irregularity, funicle surface
105	78	pattern spacing, centre surface
106	79	pattern spacing, funicle surface
107	80.1	minimum pollen-grain major axis
108	80.2	mean pollen-grain major axis
109	80.3	maximum pollen-grain major axis
110	81.1	minimum pollen-grain minor axis
111	81.2	mean pollen-grain minor axis
112	81.3	maximum pollen-grain minor axis
113	82	number of colpi
114	83	% coverage of ektexine
115	84	height of outermost surface irregularities
116	85	number of surface irregularities per unit area
117	86	exine thickness

Table 2: Morphological characters used.

string number	character number	Character description
1	1	number of locules per capsule
20	17.1	minimum length, larger leaf of a pair
21	17.2	mean length, larger leaf of a pair
22	17.3	maximum length, larger leaf of a pair
23	18.1	minimum diameter, larger leaf of a pair
24	18.2	mean diameter, larger leaf of a pair
25	18.3	maximum diameter, larger leaf of a pair
26	19	extent of leaf keel
27	20.1	lightest flower colour
28	20.2	deepest flower colour
29	21	depth of body colour
30	22	clump diameter
31	23.1	minimum petals per flower
32	23.2	maximum petals per flower
33	24.1	minimum stamens per flower
34	24.2	maximum stamens per flower
35	25.1	minimum staminodes per flower
36	25.2	maximum staminodes per flower
37	26	number of sepals per flower
38	27	number of bracts per flower
39	28.1	minimum length of petals
40	28.2	mean length of petals
41	28.3	maximum length of petals
42	29.1	minimum length of filaments
43	29.2	mean length of filaments
44	29.3	maximum length of filaments
45	30.1	minimum length of staminodes
46	30.2	mean length of staminodes
47	30.3	maximum length of staminodes
48	31	maximum length of sepals
49	32	maximum length of bracts
50	33	maximum width of petals
51	34	maximum width of sepals
52	35	maximum width of bracts

string number	character number	character description
53	36	extent of possession of a woody rootstock
54	37	length of fissure, as % body width
55	38.1	minimum length, smaller leaf of a pair
56	38.2	mean length, smaller leaf of a pair
57	38.3	maximum length, smaller leaf of a pair
58	39.1	minimum diameter, smaller leaf of a pair
59	39.2	mean diameter, smaller leaf of a pair
60	39.3	maximum diameter, smaller leaf of a pair
61	40	length of peduncle
62	41	diameter of peduncle
63	42	minor axis of peduncle
64	43	flower diameter
65	44	diameter, top of dry capsule
66	45	depth, top of dry capsule
67	46	length, lesser sepals
68	47	width, lesser sepals
69	48	number of series of petals
70	49.1	minimum stigma length
71	49.2	mean stigma length
72	49.3	maximum stigma length
73	50	length of leaf sheath
118	87	area of covering membrane as % of area of locule
119	88	size of valve wings, as % length of valve
120	89	extent of separation of valve and wings
121	90	separation of membranes on adjacent locule walls
122	91	length of covering membranes
123	92	width of covering membranes
124	93	length of valve wings
125	94	width of valve wings

Table 3 Performance characters used.

string number	char-acter number	Character description
74	51	% flowering in January
75	52	% flowering in February
76	53	% flowering in March
77	54	% flowering in April
78	55	% flowering in May
79	56	% flowering in June
80	57	% flowering in July
81	58	% flowering in August
82	59	% flowering in September
83	60	% flowering in October
84	61	% flowering in November
85	62	% flowering in December

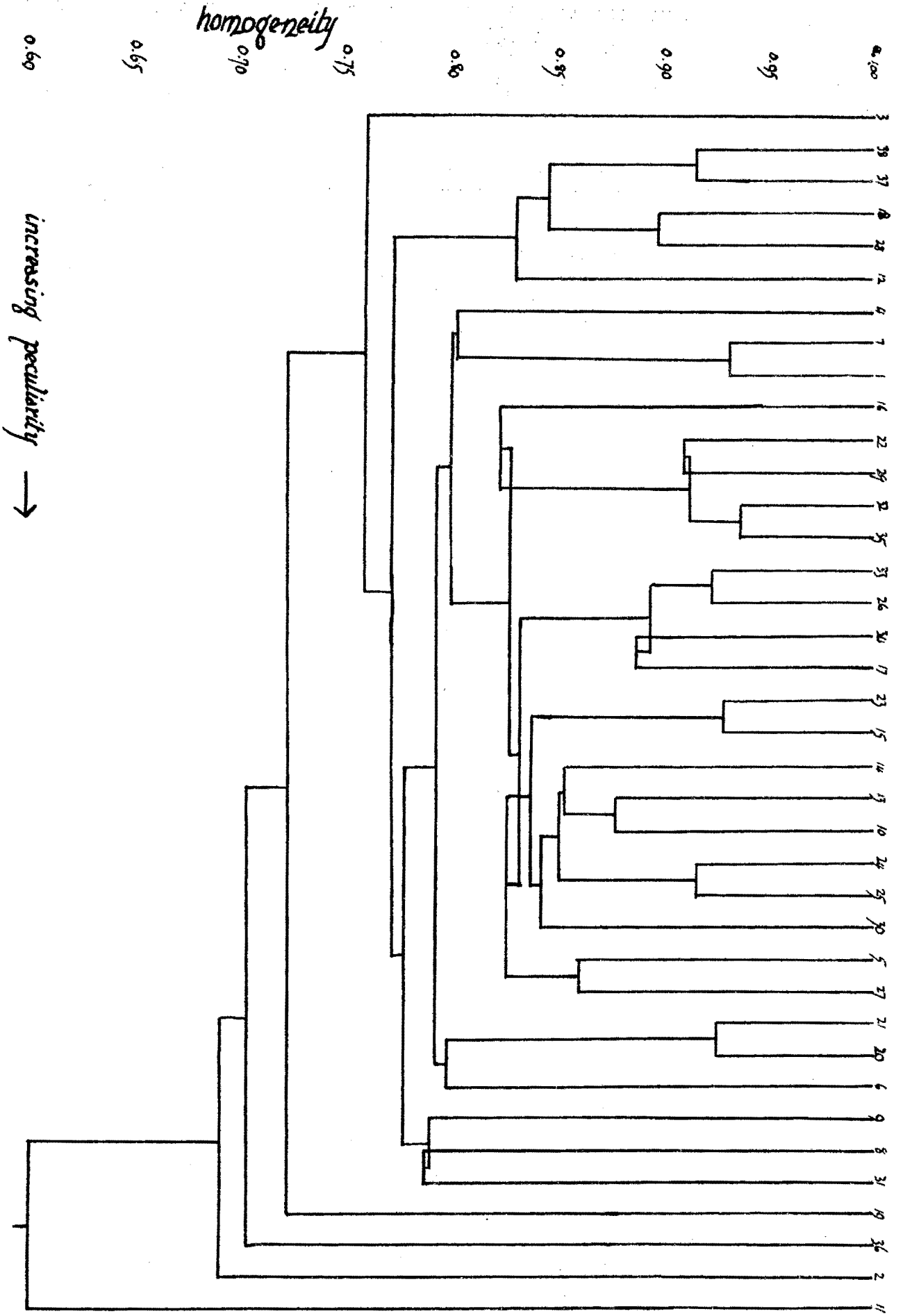


Fig. 1. Dendrogram upon which the present classification is based. Numbers on the 1.00 homogeneity line refer to OTU's in this study.

4. RESULTS AND DISCUSSION

4.1 General morphology and anatomy

4.1.1 Habit

The species of the Gibbaeinae have three kinds of habit. They may form mats, or cushions, or they may be dwarf succulents, in which case they may have their leaf apices at or above ground level.

Mat or carpet forming plants have much-branched stems, and the branches all have one or more pairs of functioning leaves at their apices. Mat-formers tend to have long, trailing stems, so that the area covered is much larger than the height of the plant. Cushion-formers have a more erect habit, and the diameter and height of the plant are more nearly equal. For this reason they may occasionally act as traps for blown sand.

Dwarf succulent plants very rarely, if ever, have more than one functioning leaf-pair per branch. The branches are much more compact than in the above forms, and stems appear to branch less frequently. Thus counts of dead leaf-bases on branches of randomly-selected "four-headed" plants, i.e. plants with four leaf-pairs, indicated that such plants were 30 - 50 years old. Young plants of most cushion-forming species may appear to have this habit. Dwarf succulent plants may have their leaves above or below ground level; in the latter case the leaf apices are at ground level.

Under cultivation, internodes tend to elongate if the plants are given too much water and not enough light. The result is that the branching becomes lax,

and the plants become prostrate, forming loose mats and losing all resemblance to field specimens.

The usefulness of this character complex alone in identifying plants of this group is minimal, as intra-specific variability frequently masks interspecific differences.

4.1.2 Leaves

4.1.2.1 Morphology

Leaves of Gibbaeinae fall into three of the main shape groups found in the Mesembryanthemaceae (Ihlenfeldt, 1960, 1971a), being triquetrous, digitiform or hemispherical to hemi-ovoid. Leaves in this last group may or may not be keeled. These shape-groups are useful as a first approximation, but within each group there is much variation. For example, the leaves of G. velutinum are triquetrous, but not symmetrical, being much deeper than wide, while the leaves of G. pachypodium are symmetrically triquetrous. As another example, the leaves of G. nebrownii could be classed as hemispherical, but are flat-topped (quarter-spherical or semihemispherical), while those of G. heathii are truly hemispherical.

Triquetrous and digitiform leaves do not change shape to any great extent under cultivation, but they may change markedly in size. Hemispherical leaves tend to become elongated under conditions of insufficient light and too much water, particularly in the case of G. heathii. It was noticed that some individuals of Muiria hortenseae became grossly elongated in the field after exceptional

rains (June 1974), and some plants then showed signs of a small leaf fissure.

To some extent, the colour of the leaves is a valuable diagnostic character in the field. Leaves of the different species may be white, glaucous, yellowish, reddish, brown or various shades of green. At least some of these shades are attributable to the physiological state of the plant rather than being taxonomically important. Thus G. geminum and G. pachypodium are grey to brown in normal to dry field conditions; after very good rains (June 1974) plants in the field were various shades of olive green. Attempts have been made to accord taxonomic status to individuals of G. gibbosum with unusual leaf colouration. Those with leaves more yellow than normal were alleged to be a tetraploid species, G. luteoviride, and those with unusually green leaves were called G. perviride. However, by manipulating the supply of water and trace elements to a plant, it is possible to produce a plant that belongs to three different species at different times. Likewise, individual plants in the field may have branches belonging to different "species" at one and the same time.

In general, plants cultivated under conditions of inadequate light and overabundant water tend to become grass-green or emerald green.

The four characters, habit, leaf shape, leaf-colour and pubescence (discussed below) are sufficient for field identification of all species in the Gibbaeinae.

4.1.2.2 Anatomy

Reule (1936) was the first to examine the epidermal anatomy of Mesembryanthemaceae microscopically. He examined 81 species (out of a possible 2 300) and found a considerable range of variation. He divided this range into six "types", some of which appear to have been represented by but a single specimen, and a number of individuals fitting into no one type. The six members of the Gibbaeinae that he studied were found to include two individuals not assigned to types, and four distributed between more than one type.

Ötzig (1940) studied the epidermal structure of seventy species of Mesembryanthemaceae in great detail. He found some intraspecific variability, but attributed most of the variation he found to ecological factors. This study was more concerned with general similarities than specific differences.

Prior to the present study, therefore, epidermal characters had hardly been considered in the study of the taxonomy of the Gibbaeinae. In his key, Nel (1953) made the following distinctions:-

leaves hairy or glabrous,

hairs simple or stellate,

hairs erect or appressed.

All these characters can be seen with a hand-lens. He did not consider cell characters or the branch structure of the hairs, nor did he consider hair characters consistently throughout the group.

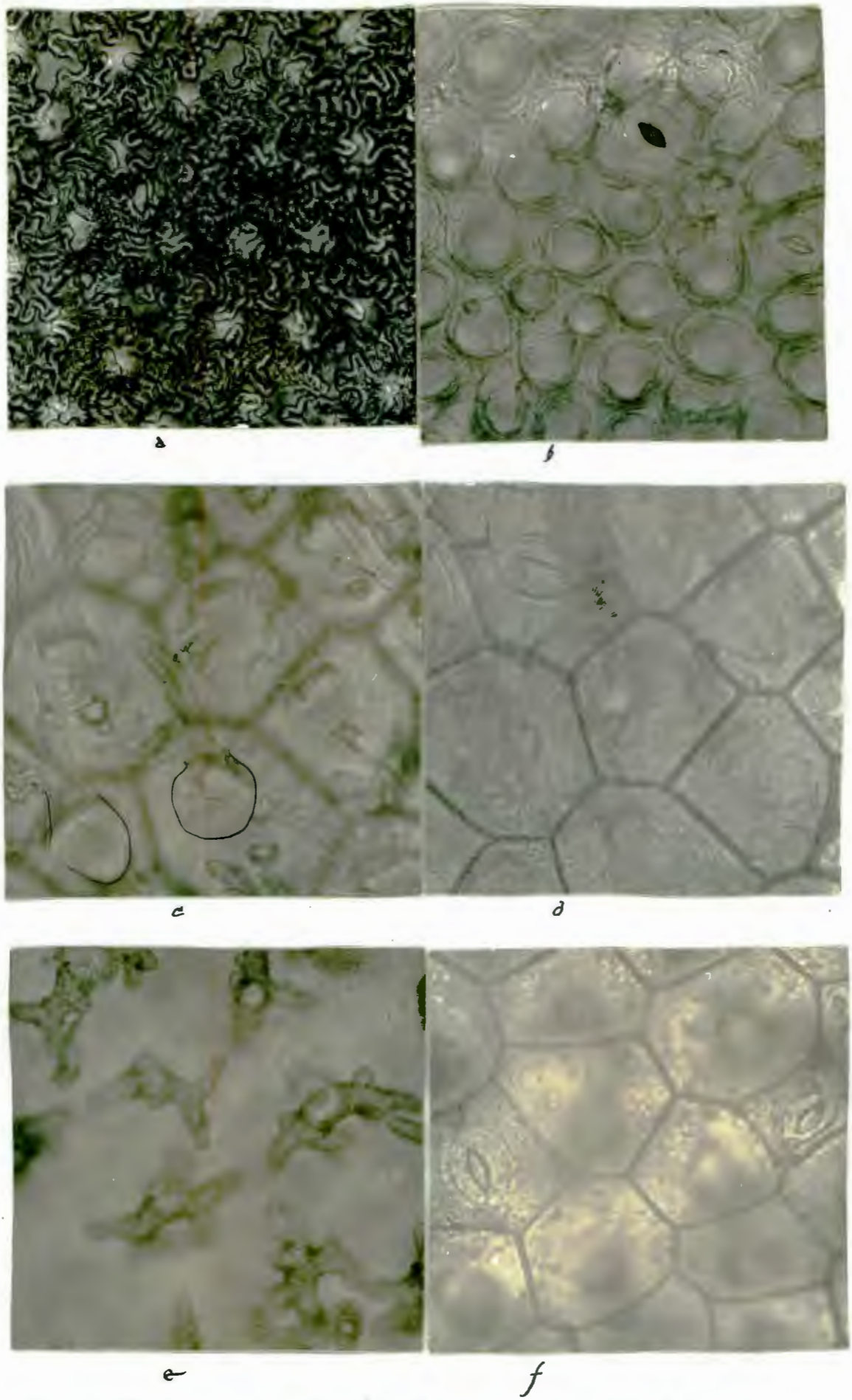
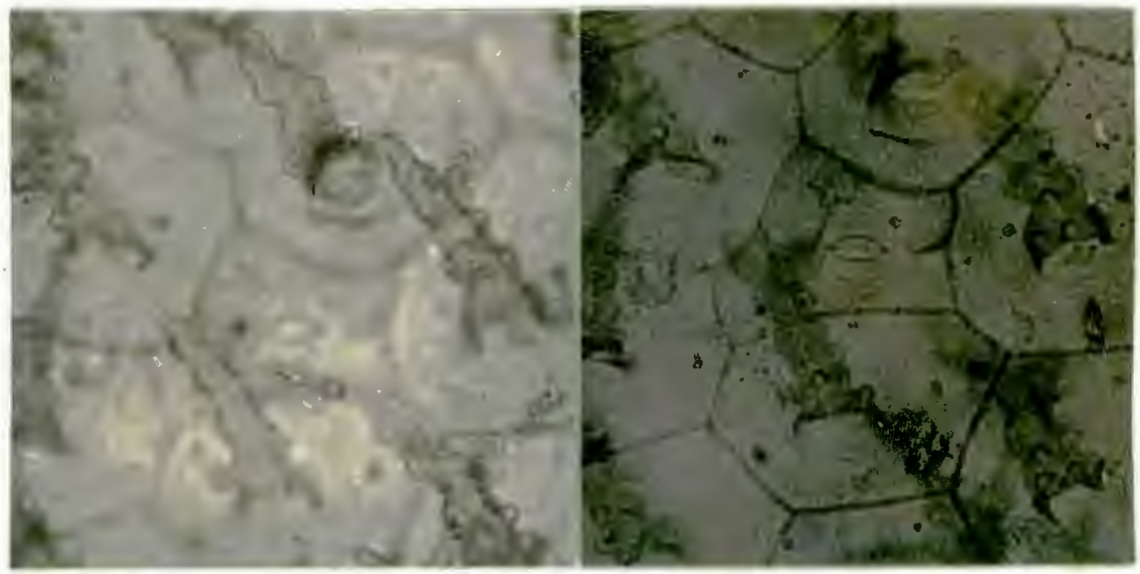
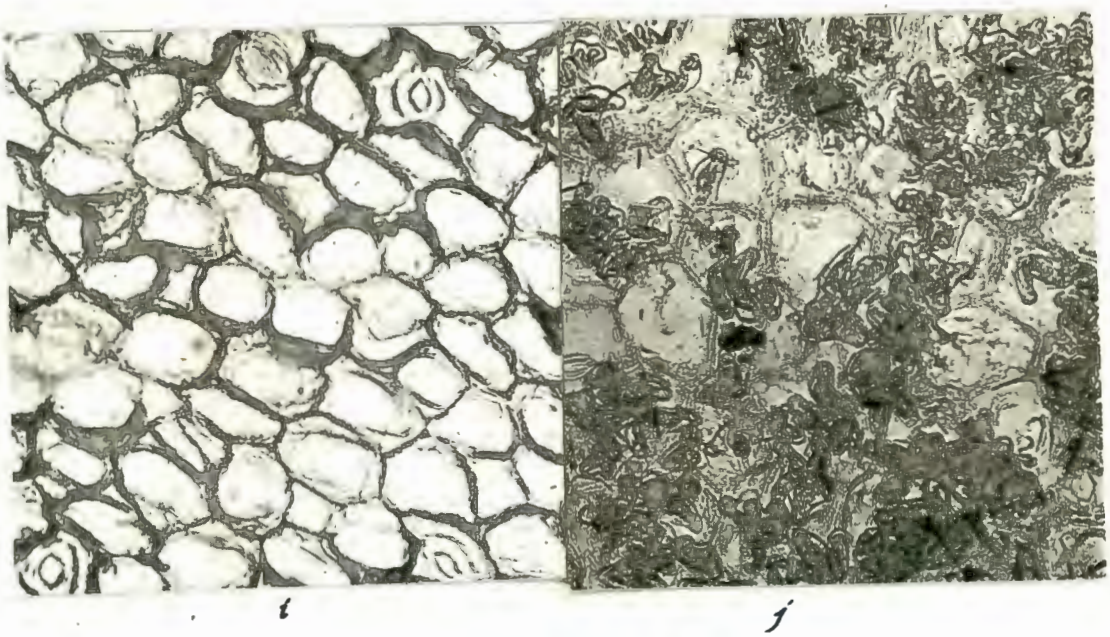


fig. 2. Epidermal anatomy of members of the Gibberinae. (a). G. album, hairs. (b) G. album, cells. (c) G. angulipes, hairs. (d) G. angulipes, cells. (e). G. austricolum, hairs. (f) G. austricolum, cells. All x325.



g h



i j

Fig. 2 continued. (g) G. dispar, hairs. (h) G. dispar, cells. (i) G. esterhuysenise (j) G. geminum. All x325

It should be noted that epidermal characters are not necessarily of taxonomic value in all succulent plants, nor even in all groups of the Mesembryanthemaceae. For example, a brief examination of a few specimens of Stapelieae (Asclepiadaceae) showed more variation within a species than between genera, and very little intra-specific variation. According to Poppendieck (pers. comm.) the epidermal anatomy of the Mitrophyllinae (Mesembryanthemaceae) is also uniform throughout the group.

For identification purposes, it will rarely be necessary to make a cuticle preparation according to the method of section 3. Most important characters can be seen on living or dried material with a stereo (dissecting) microscope and fifty-power magnification.

The epidermal surface anatomy provides a rich complex of characters, which enable any taxon in the Gibbaeinae to be identified with the minimum of material.

The epidermal character of prime importance is the presence or absence of an indumentum. In the Gibbaeinae twelve taxa (eleven species and one subspecies) have an indumentum and seven are glabrous. Amongst the pubescent taxa, useful characters include simple or branched trichomes (six taxa have simple trichomes, five branched and one has strains with both simple and branched trichomes), the structure of the trichome wall - simple, corrugated or tuberculate - the manner of branching and the disposition of the branches. Branched hairs may be once to several times dichotomously branched, or one

branch may overtop the other, or there may be more than two branches arising from one branch point. The branches from the lowest branch point may be as long as the main axis below it, or branching may commence only near the apex of the hair. In some species, hairs are found on all epidermal cells except those associated with the stomata, while in others they are restricted to the larger epidermal cells only.

Gibbaeum album is unique in that the branches of the hairs interlock, giving the outer surface of the leaf a highly distinctive appearance. The possible ecological advantages of this would be threefold, two arising from the thin air layer trapped between the interlocked trichome-branches and the epidermis itself. Firstly, this air layer would provide some insulation from the large difference between day and night temperatures, and secondly, it would become saturated with water vapour, thus possibly reducing transpiration. Thirdly, the hairs would reflect much of the incident light and heat.

Among the glabrous taxa, one must use characters which, although present in hairy taxa, are sometimes hidden by the trichomes, and are rarely as convenient to use as trichome characters. As the characters in question are all cell-characters, they are very difficult to see with a dissecting microscope.

In some taxa the epidermal cells are of two distinct sizes, while in others smaller cells are absent or very rare. Some taxa tend to have relatively large

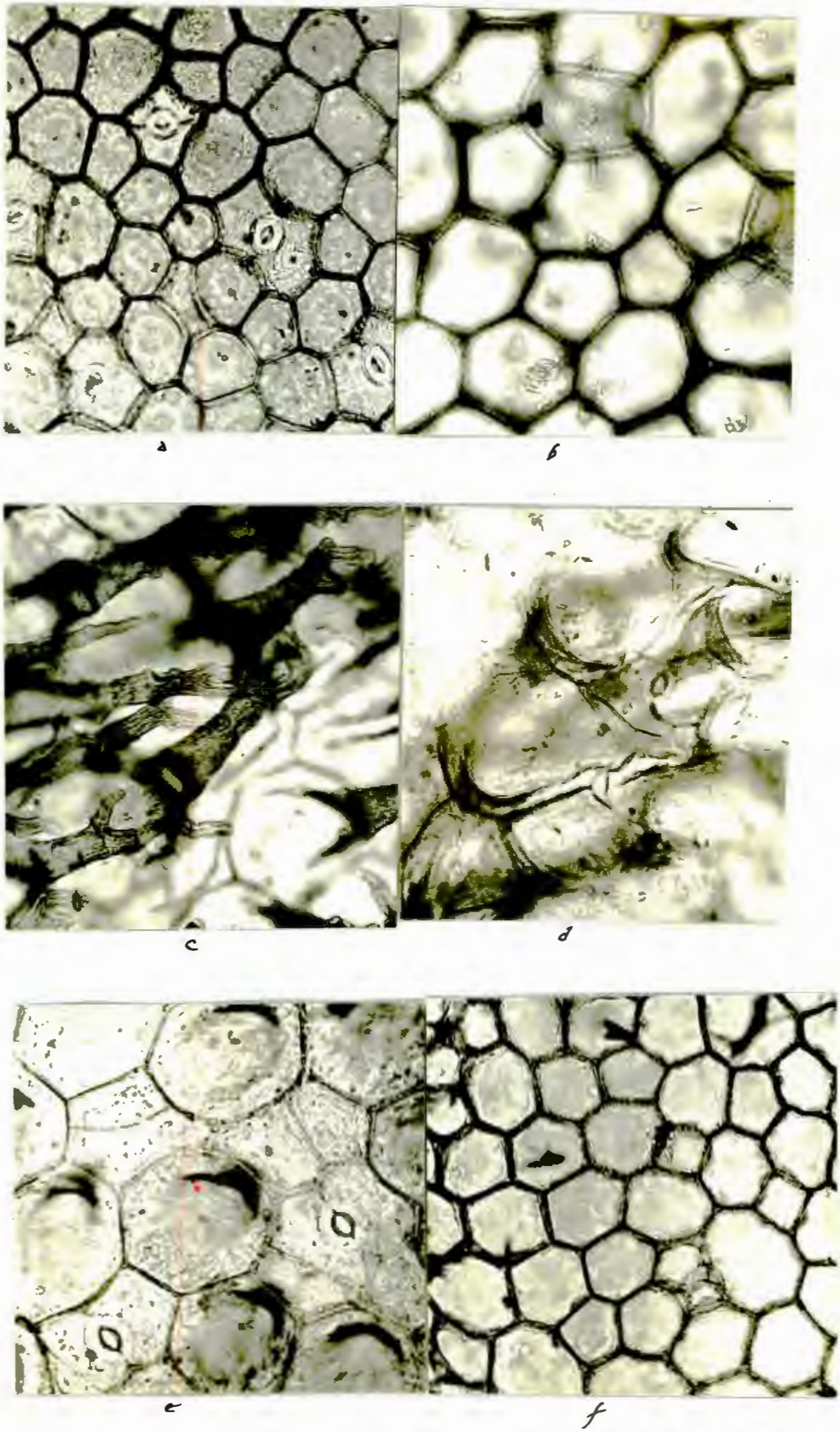


Fig. 3. Epidermal anatomy of members of the Gibbaeinae. (a) G. gibbosum. (b) G. healthii. (c) G. nebrownii, hairs. (d) G. nebrownii, cells. (e) G. muciforme. (f) G. petrense. All ×325.

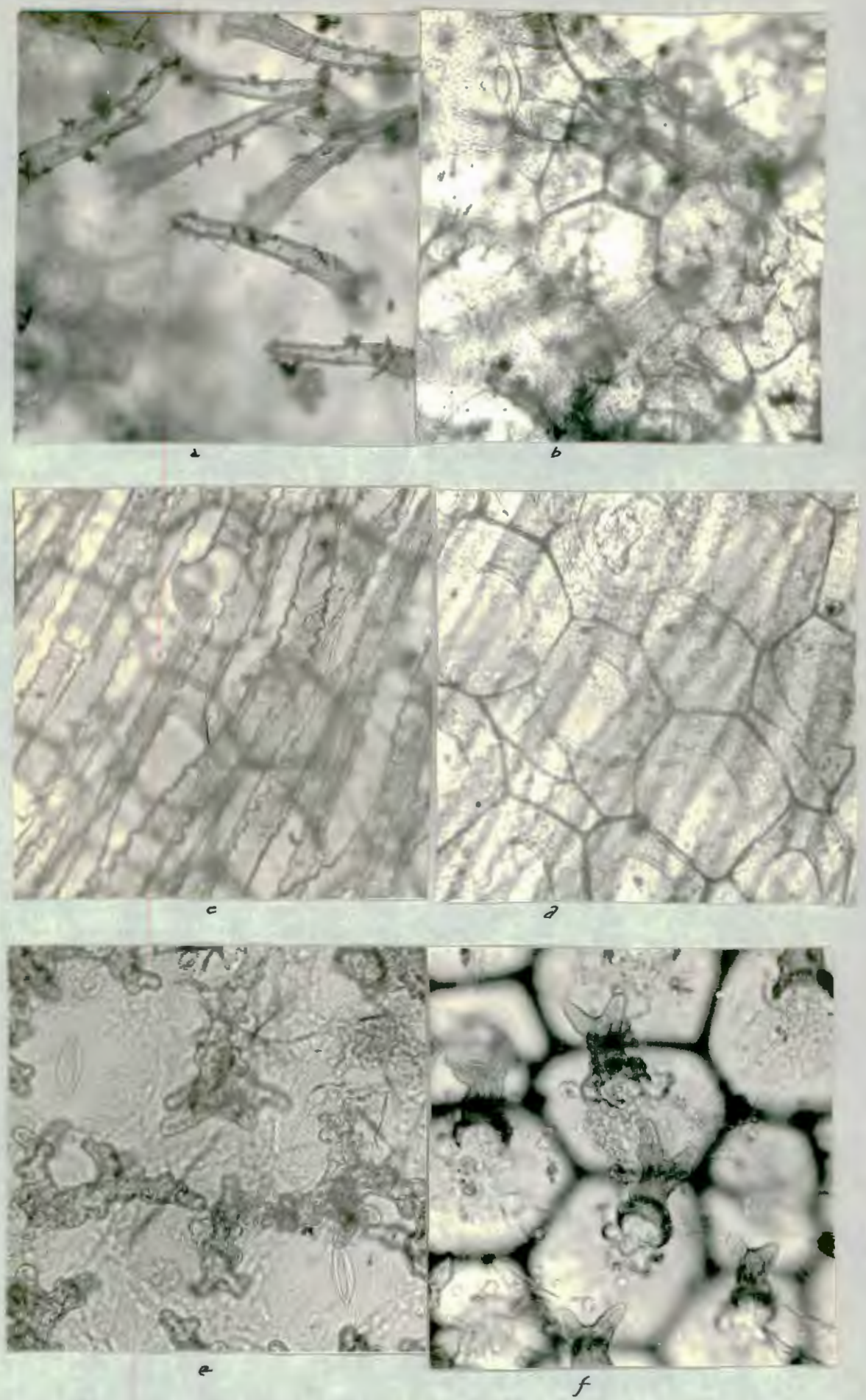
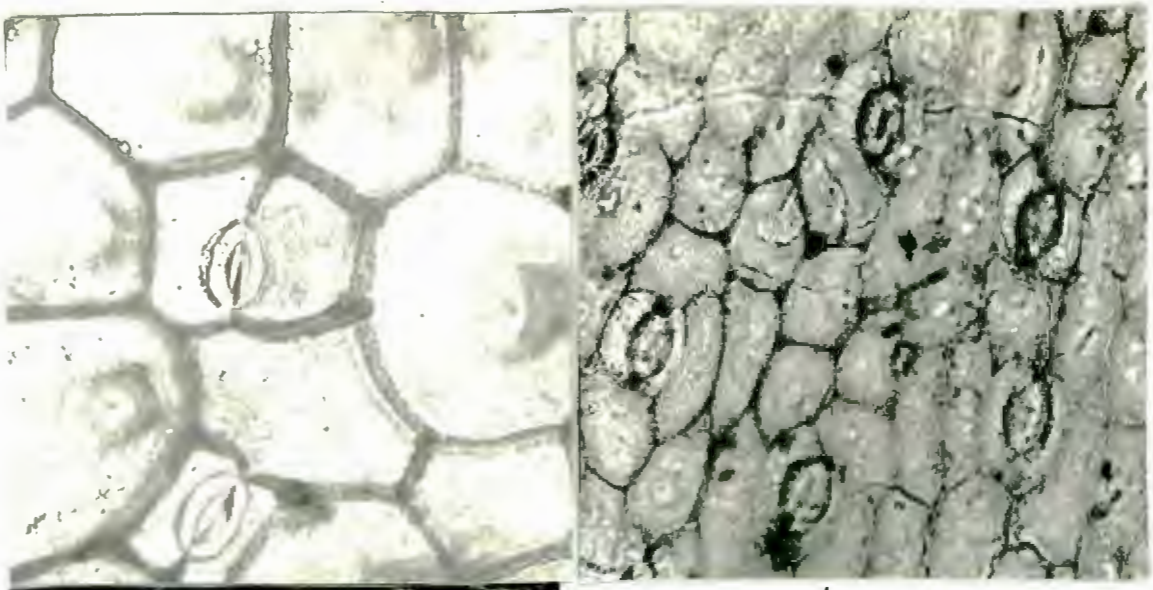
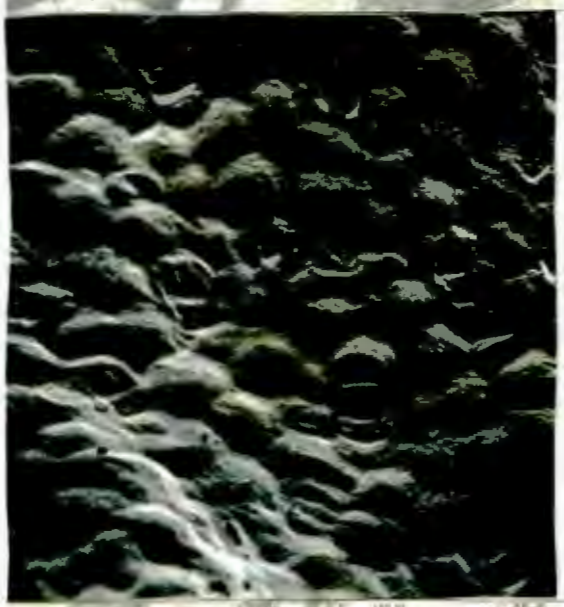


Fig 4. Epidermal anatomy of members of the Gibbsiae. (a) G. pachypodium, hairs. (b) G. pachypodium, cells. (c) G. pubescens subsp. pubescens, hairs. (d) G. pubescens subsp pubescens, cells. (e) G. pubescens subsp. shandii. (f) G. velutinum, hairs. All X325.



a b



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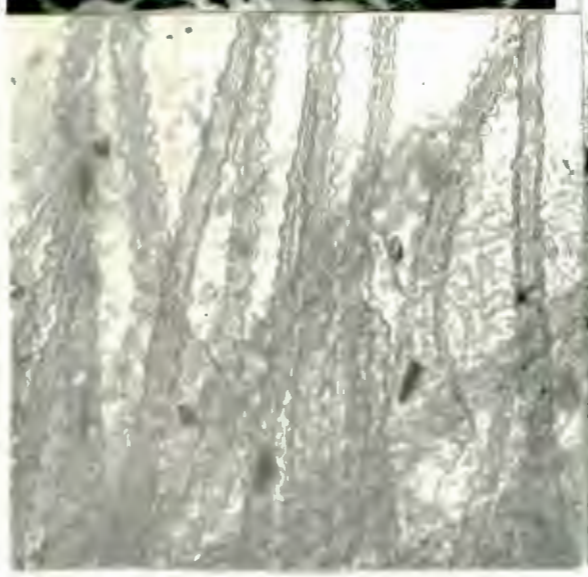


d e

Fig. 5. Epidermal anatomy of members of the Gibberinae. (a) G. velutinum, cells. (b) A. fissoides. (c) D. lepidiformis. (d) M. hortensese, hairs. (e) M. hortensese, cells. a, b, d, e ×325; c ×375

epidermal cells, while others have small ones. In some taxa the cells are more or less regularly arranged, while in others several cells will occasionally be clustered around a central cell, which will have a different shape but not necessarily a significantly different size. The outer wall of each cell may be flat, domed or variously patterned. Finally, the stomatal ratio may be useful, although intraspecific variation in this character is large.

Identification of glabrous specimens by the use of epidermal characters alone is possible, but it is a much more arduous and less certain task than identifying specimens with trichomes under the same circumstances.

Didymaotus lapidiformis is unique among glabrous taxa in that plants have a thick layer of wax on the cuticle, so that microscopical preparations of the cuticle take up Sudan III to produce an even, detailless red layer, unless care is taken to remove the wax before making the preparation.

Dugdale (1971) has described a method for fixing and making visible, tanniniferous idioblasts in succulent leaves. He claims that it is possible to use these idioblasts as taxonomically valuable characters. In the present study it was not found possible to support that claim. It was found that the inter-taxon similarities far outweighed any differences, which were masked further by relatively slight intra-taxon variation. Tölken (pers. comm.) reports similar conclusions in Crassula.

4.1.3 Rootstock.

Some species in the group have a large, woody rootstock, which is, however, not as large as those common in Trichodiadema or Mestoklema. Others have a much smaller root system, in which the main root is no larger than the larger lateral roots, almost a fusiform root system. Although this may possibly be used as a secondary character in identification, it is not recommended as the roots are rarely present on herbarium specimens, and in the field other characters which yield the same amount of information can be found without digging up any plants.

4.1.4 The inflorescence

The flowers in this group are solitary and terminal throughout except in Didymaotus lapidiformis, where two opposite, lateral, one-flowered inflorescences are borne simultaneously.

4.1.4.1 Bracts.

Bracts are absent except in Antegibbaeum fissoides and Didymaotus lapidiformis. In the former they are small, triquetrous and connate at the base to form a sheath which covers the lower half of the peduncle. The apices of the bracts do not reach the base of the receptacle and are not conspicuous before anthesis.

In Didymaotus, the bracts appear many months before anthesis, and being much deeper and wider than long, so as to appear like miniatures of the true leaves, give the plant the appearance of having an offset on either side of the plant. The bracts are near the base of the peduncle, and the apices of the bracts are relatively far from the receptacle at anthesis.

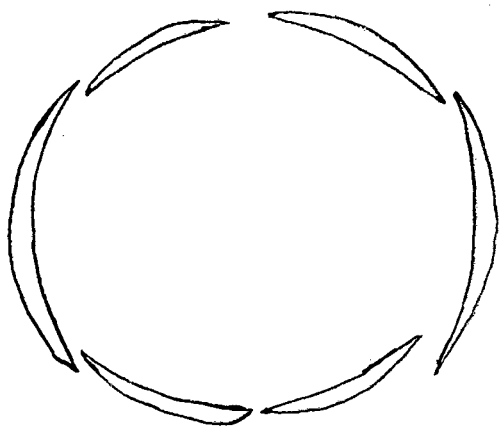


Figure 6. Arrangement of the perianth in Gibbsiinae. One more inner part (inner) sepal) than shown may be present, or one of those shown may be absent.

4.1.4.2 The Calyx

As Ihlenfeldt (1960) and Ihlenfeldt and Jörgensen (1973) point out, the "calyx" in Mesembryanthemaceae is actually a perianth composed of sepaloid segments. However, it is customary among students of this family to refer to the perianth as a calyx. In the Gibbaeinae it usually consists of six sepals (perianth parts), but may be seven or rarely five. These sepals are arranged in two whorls, with two in the outer and four (three or five) in the inner (fig. 6). The sepals in the outer whorl are often larger or much larger and more leaflike than those of the inner whorl; rarely they are identical to those in the inner whorl. When leaflike, they are oblong to narrowly deltoid, with an acute to obtuse apex. They are often succulent, in which case they are triquetrous to radially compressed in section.

The inner sepals usually have membranous margins, so that the overall shape is oblong with an obtuse apex.

4.1.4.3 The androecium

The androecium of the Mesembryanthemaceae was studied in detail by Ihlenfeldt (1960), who grouped androecia into three types on ontogenetic grounds. It was found that types II and III occur in the Gibbaeinae.

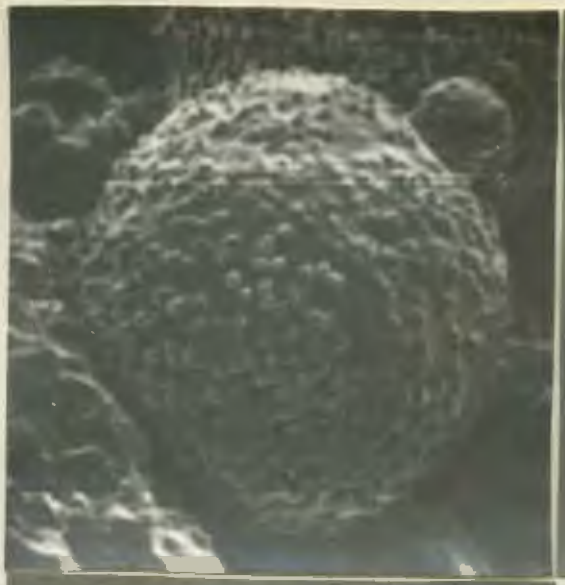
In the type II androecium, stamens, a relatively small number of nonpetaloid staminodes and a larger or smaller number of petaloid staminodes are formed, with few intermediates between these functional groups. The

petaloid staminodes are usually referred to as "petals" (Ihlenfeldt, ibid.; Ihlenfeldt and Jörgensen 1973). In the type III androecium, nonpetaloid staminodes are absent and the numbers of stamens and "petals" are reduced. The petaloid staminodes are customarily referred to as petals by students of the Mesembryanthemaceae.

The petals are arranged in one to four series, and all are about the same length. They continue to elongate during anthesis, but not to the extent that they do in some genera e.g. Conophytum (Rawe, pers. comm.). The number of petals in a flower is variable, and intraspecific and interspecific variation overlap to some extent. The petals of members of the Gibbaeinae are white, pink, magenta or purple, but never scarlet, orange or yellow. Gibbaeum nebrownii is unique in that the bases of the petals are fused to form a tube for about a quarter of the length of the petals.

Nonpetaloid staminodes are absent in some species, and in one or two they are variably present or absent. They vary in length from about as long as the filaments of the stamens to two or three times as long or about half as long as the petals. They are usually white, rarely pink.

The stamens are numerous, with intraspecific variation in numbers again overlapping interspecific differences to some extent. They are arranged in several series, and are mostly white, but occasionally yellow or pink (this last most pronounced in Didymaotus).



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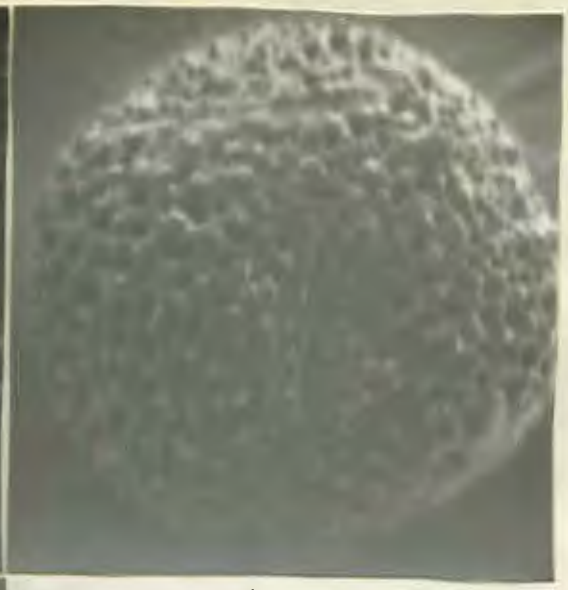

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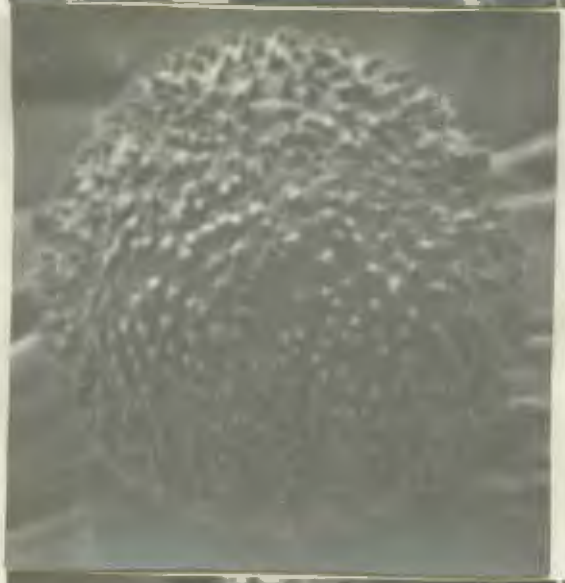

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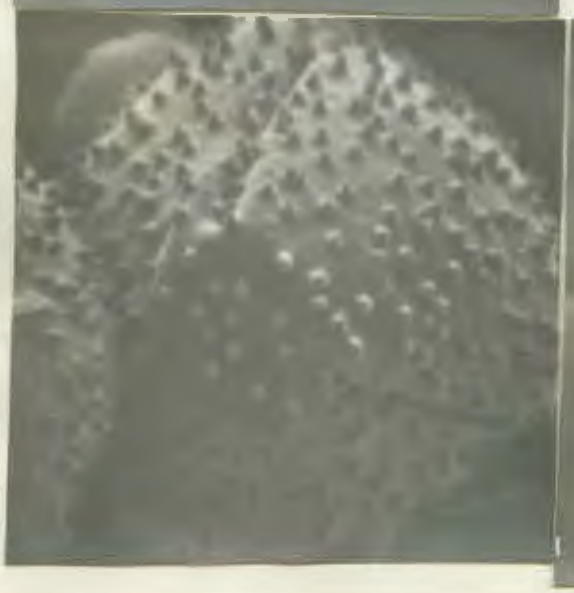


d

e

Fig. 7k. Pollen of members of the Gibbaeinae. (a) G. velutinum (b) G. nebrownii. (c) A. frissoides (d). D. lapidiformis. (e) M. fortbenense a x3600; b,c x4150; d,e x4500.

In this group the pollen is very uniform, with little intergeneric and less intrageneric variation. Pollen grains of the different genera are shown in fig. 7. The pollen in this group is yellow.

4.1.4.4 Gynaecium and nectaries

The ovary in the Gibbaeinae, as in all members of the Ruschioideae, is inferior. Most members of this subtribe have six-locular ovaries, except G. heathii, which normally has eight-locular ones. Aberrant individuals with seven- or nine-locular ovaries are not uncommon, and there are reports in the literature of five- and ten-locular ovaries. All species show parietal placentation at anthesis.

In Gibbaeum and Antegibbaeum the ripe capsule is obconical to campanulate; in Didymaotus it is discoid to lens-shaped. Cell membranes cover the locules of Gibbaeum capsules almost completely; in Antegibbaeum and Didymaotus the membrane over each locule is split to the columella, but the two parts cover by far the greater part of the locule. There are no placental tubercles in these three genera, but valve wings are present in all of them. Muiria lacks cell membranes, valve wings and placental tubercles. In the laboratory, ripe capsules open slowly on soaking for about five minutes, and close within an hour if blotted dry and warmed gently (e.g., put in a sunny window). In the field, the ripe capsules are opened by a heavy overnight dew. Seeds are ejected by raindrops in the manner described by Garside and Lockyer (1930), Volk (1960) and Ihlenfeldt (1971b).

The nectaries in the Gibbaeinae are lophomorphic meronectaries, generally but not always equal in number to the locules of the ovary.

4.1.4.5 The Seeds

Most seeds of members of the Gibbaeinae have the shape that appears to characterise Mesembryanthemaceae; these seeds are triangular-ovoid, with a distinct conical funicle at one end. The testae of the seeds are patterned with papillae or tubercles, some of which in turn are patterned. These patterns are variable, with intraspecific variation often but not always overlapping interspecific differences. The testa is surprisingly delicate, and it was found that the pattern was distorted or destroyed easily, by any rough treatment in preparation and observation.

Cole (pers. comm.) found very similar patterns in Lithops. In fact, comparing his photographs with mine, it was impossible to determine to which genus the seeds depicted belonged, without noting the style in which the photographs were printed. However, within both genera there are specific differences. Thus one could say, for example, that a particular photograph showed seed of Gibbaeum pubescens or Lithops bella, but one could not say which of the two on the basis of the seed alone.

Antegibbaeum fissoides is unique in the group in having echinate seeds. The seeds of this species show no distinct funicle, but are approximately tetrahedral. All faces of the seed are covered with long, roughly cylindrical papillae, though in some parts of the seed

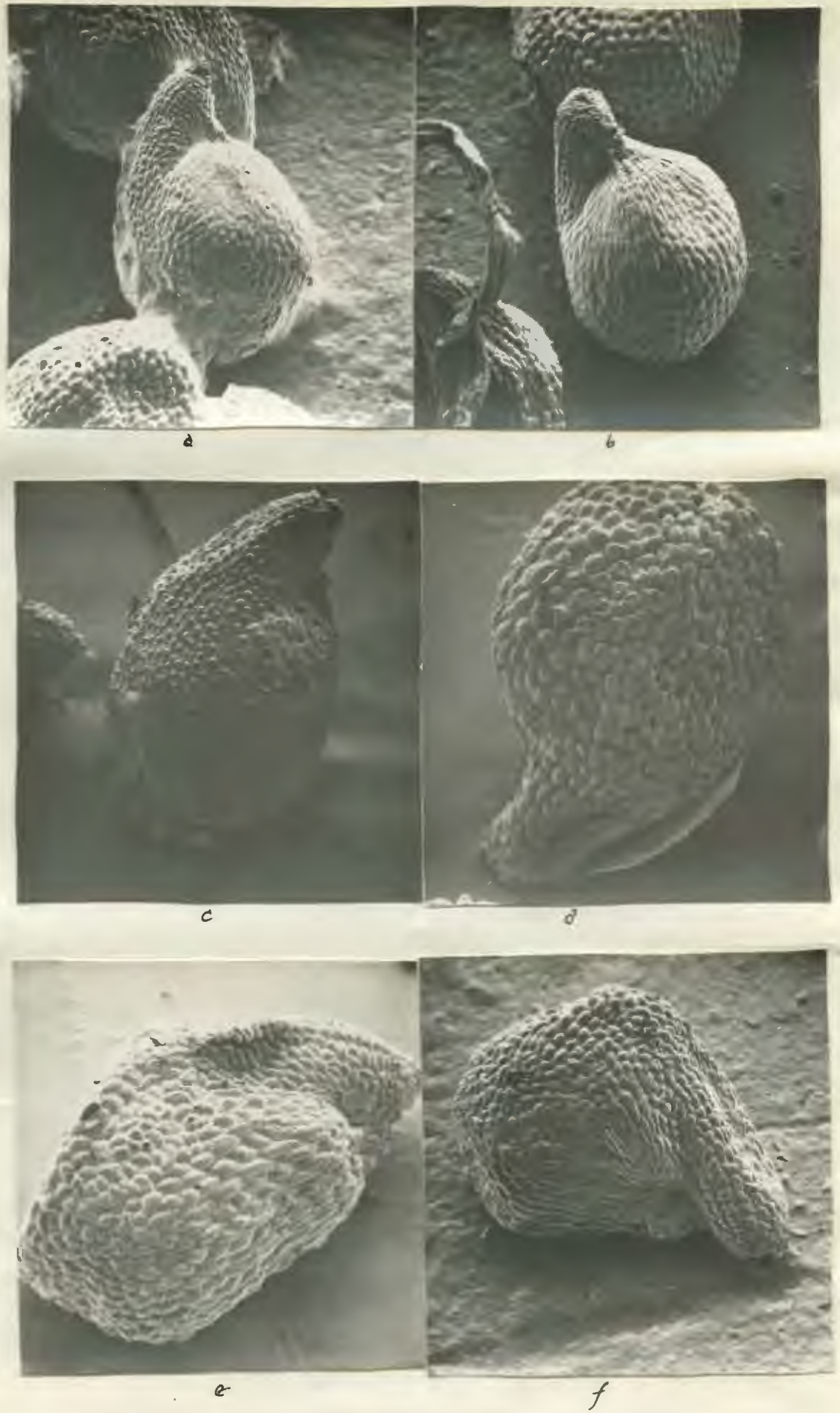
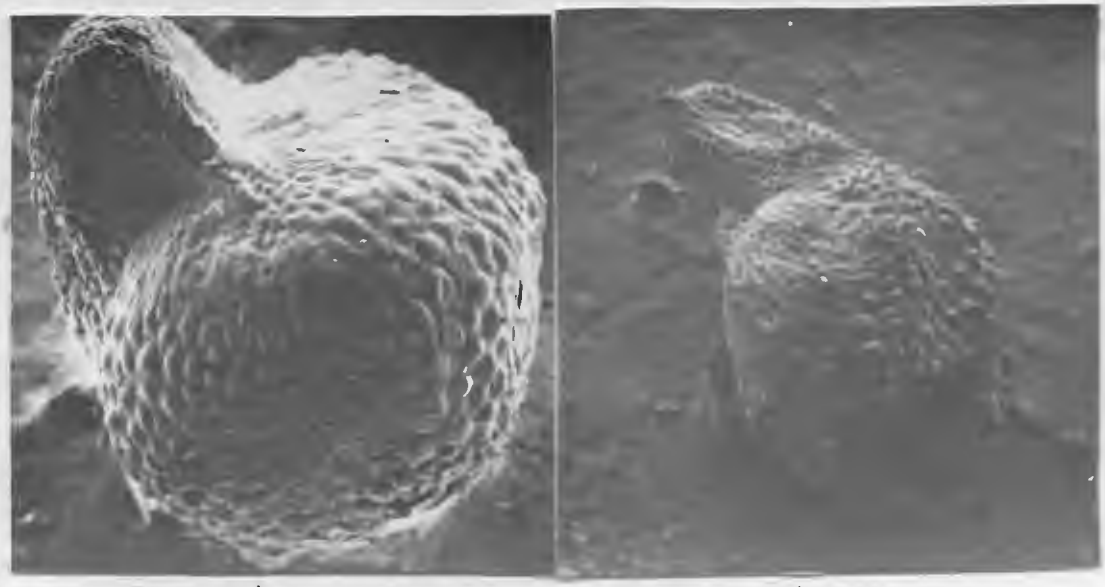


Fig 8. Seeds of members of the Gibbsiinae. (a) G. gibbosum, (b) G. heathii, (c) G. nebrownii (d) G. nicifornae (e) G. pachypodium. (f) G. petrense M1 x 40



a b

c d

e

Fig. 9. Seeds of members of the Gibbaeinae (a) G. pilosulum (b) G. pubescens subsp. pubescens (c) G. pubescens subsp. shandii (d) G. velutinum. (e) D. lapidiformis a x 180; b, c, d x 90; e x 135

f

g

Fig. 9. continued. (f) A. fissoides, whole seed, x40. (g) A. fissoides, detail, x1500

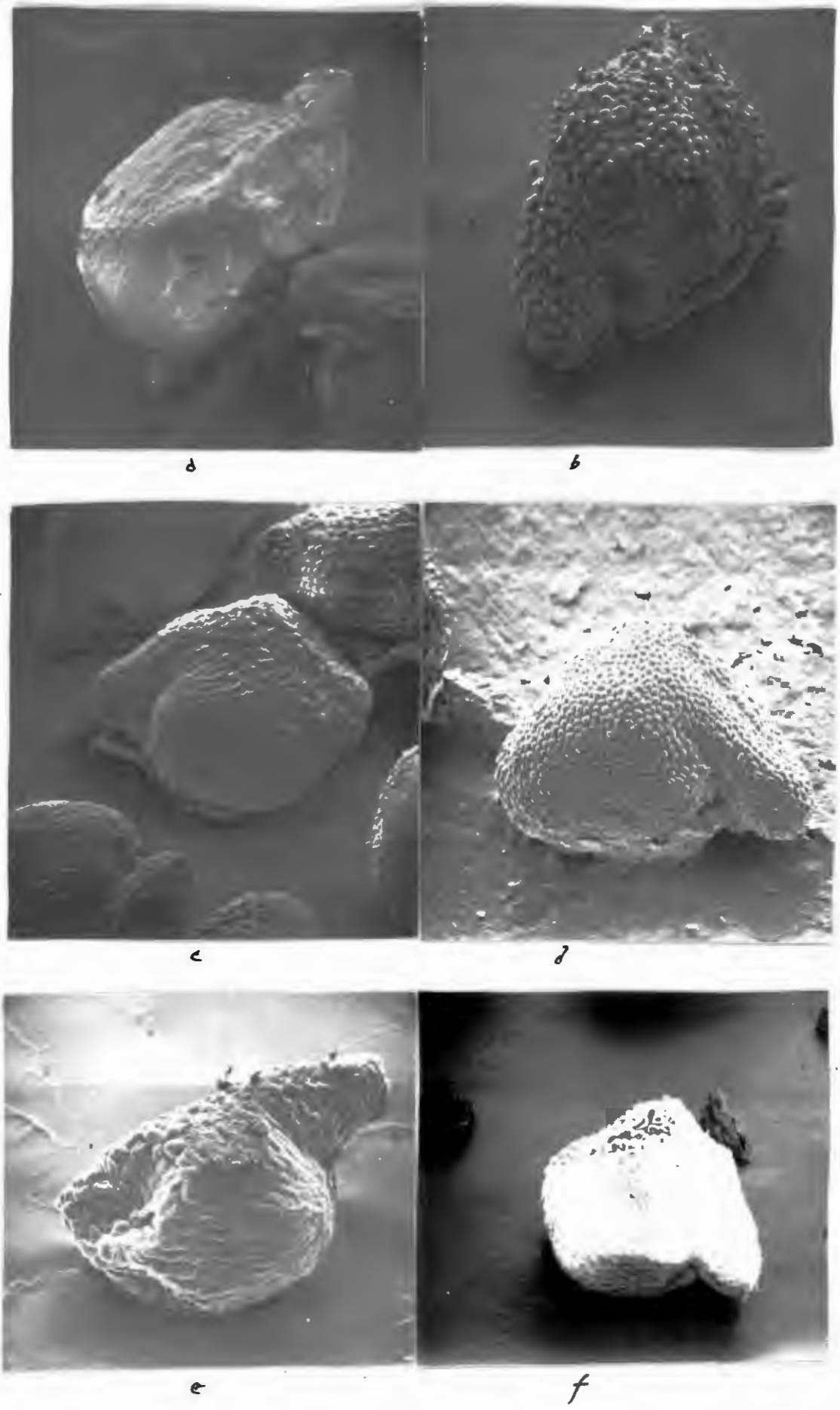


Fig 10. Seeds of members of the Gibbsiinae. (a) G. album. (b) G. angulipes (c) G. australicolum (d) G. disper (e) G. osterhuysense (f) G. geminum. a, b, d, e x 90; c, f x 75

they are longer than in others. These papillae have secondary cylindrical outgrowths of unknown nature (possibly wax) upon them. Similar seeds are found in Braunsia and Astridia, and other genera (Haas, pers. comm.).

Seeds of members of the Gibbaeinae are pale brown, maroon-brown, chocolate-coloured or black (Antegibbaeum). A representative selection are shown in figures 8 - 10.

4.2 Interpretation of the numerical data

Before one can begin to argue about the relative merits of adhering to or deviating from the results of the numerical studies at any point, one must first examine the properties of the data matrix and the resulting phenogram. It is particularly revealing to examine the stability of the groups illustrated by the phenogram with respect to the number of characters employed in the study, and with respect to the extent of error or weighting in the characters used. It can be shown empirically that most numerical classifications are mainly dependent on inter-OTU size differences, and the number of different kinds of character, but only minimally on the actual number of characters and any weighting applied to these. The present classification is no exception to this generalisation.

Jardine (1971) showed empirically that in his study of infraspecific variation in humans, the addition of each character to the pre-existing matrix affected the result less than the addition of the character before, and the individual contributions of characters after the fifteenth were not significant. It was suspected, however, that the addition of measured characters would have changed this result quantitatively but not qualitatively.

Sneath and Sokal (1973) record the early suggestion, which has been found empirically to be satisfactory, that a minimum of sixty characters and preferably more, be used. They note that not all characters of an OTU are necessarily independent, but rather that a set of characters can usually be broken down into suites relating to different parts or phases of the organism. They also remark on a principle of inertia, that the more characters there are in a study, the more characters have to be added to the matrix in order to modify the results significantly.

These observations were borne out in the present study. Many group-forming runs were done, with numbers of OTU's increasing from six to 38 and numbers of characters increasing from six to a hundred (the number of character strings increasing from six to 131).

One of the earliest runs was with 35 OTU's and 17 character strings. All characters except one were related to the epidermal anatomy of the leaves. The major division resulting from this was into "hairy" and "hairless" plants. The addition of eight strings related to chromosome number and leaf dimensions resulted in position shifts involving almost all of the OTU's, resulting both from changes in the homogeneity levels at which clustering occurred, and changes of the identity of the OTU's in the clusters.

The penultimate data matrix involved 92 characters (123 strings) and 38 OTU's. The addition of eight properties relating to the internal morphology of capsules resulted only in minor shifts in the homogeneity levels at which some clustering occurred, but not in any

changes in the relative positions of the OTU's. This was in spite of the fact that these eight characters included some which have, previously, been regarded as being of critical value in determining the identity of specimens and the relationships of taxa.

The use of one or two OTU's, each a centroid of some ten exemplars, to represent each known name in the group, may be criticised on the grounds that it is inadequate to represent the intra-taxon variability. However, a study by Sokal (1962) to test this point, as well as incidental data from eleven other studies cited by Sneath and Sokal (1973) and this one, indicate that the error from this source is minimal.

Work published by Moss (1968) on weighting, and unpublished work by Carmichael and Sneath (reported by Sneath and Sokal, 1973:181) on relevance, indicated that the effect of both extreme weighting and up to one-third NC (not coded) entries in the matrix, make little difference to the result. The correlations cited in the latter publication, even at the highest NC rate, are significant at the 0,1% level even with very few degrees of freedom.

Moss (1968) found that if he doubled the overall size of a set of OTU's to produce a set of imaginary "giant" OTU's, and these added to the existing set of "normal" OTU's, then the "giants" would cluster between themselves to form an exact replica of the clustering pattern of the "normal" OTU's before clustering with them. This indicates that overall size differences between OTU's

do influence the clustering pattern significantly. This is the reason for the importance of extracting overall size according to the algorithm of Hall (1969c) - in this way shape characters are given meaningful extra weight.

In order to test the extent to which variation in size affected the clustering of the 38 OTU's in the present study, measured characters were divided into six groups according to their "theme" (e.g. body size, flower size, seed size, pollen size) and scaled, with an overall size factor extracted for each group, according to Hall's algorithm. This increased the number of characters from 94 to a hundred (125 to 131 strings). If overall size variation had as little effect as increasing the number of characters (above), then this should have had very little effect on the resulting dendrogram, less than the addition of the eight capsular characters. In fact, the effects of this transformation of the data matrix were relatively profound, involving both changes in the identity of OTU's involved in clustering with each other, and the homogeneity levels at which branching occurred.

4.2.1 Particular notes on the present study

Parameters detailing the constraints placed upon the processing of the data are listed at the head of the data (appendix 2) and the results (appendix 5). These will be treated in order of appearance in the lists.

Groups were formed with 100% space conservation, that is, leaving the maximum amount of space around each OTU, in order to allow any single, unusual OTU to appear as such, instead of being pushed into a group where it fits badly.

Seven properties were coded as maximum and minimum, and twelve as minimum, mean and maximum, yielding nineteen extra-value properties and 31 extra strings. This allows for showing variation in all important variable characters, as well as indicating asymmetry in the variation where there is any.

Thirty-seven properties were de-weighted. In all cases, these were groups of properties that were considered to be semi-homologous. The properties concerned were grouped into sets, each of which describes a complex character, and deweighted so that the whole group contributed the weight of a smaller integer number of characters (one or rarely three). For example, properties five to seven are three different measurements of stomata; taken together, they yield one character, stomatal size-and-shape.

Overall frequency modulation is mainly used in ecology or related areas to suppress spurious similarities due to absences. For this reason it was not used in this study.

The twelve individually-modulated characters are the extent of flowering in each month of the year. Individual modulation is necessary to suppress false similarities due to non-flowering in any particular month. These twelve characters are further deweighted to give the effect of only three characters.

The structure of the final dendrogram was abandoned in three places in the delimitation of species and genera, as detailed below.

Extensive field searches failed to reveal any plants that could be referred to G. haagei and G. esterhuyseniae. In the former case, a literature study revealed that this confused concept consists of elements more properly belonging to two, not one, other, valid taxa. G. esterhuyseniae is probably extinct.

Gibbaeum velutinum and G. schwantesii are united into one species despite the low homogeneity at which they unite on the dendrogram. If, however, one examines the homogeneity values between the various elements 10, 13, 14, 24, 25, 30 of G. heathii and G. nuciforme (15, 23), pair by pair, and averages them, and then does the same for G. velutinum s. str. (18, 28) and G. schwantesii (12), and compares the results, one finds that the mean similarity between G. heathii and G. nuciforme, at 0,811 ± 0,004 is significantly less than that between the elements of G. velutinum (0,833 ± 0,019). Also, field studies show the existence of a complete range of intermediates between the three exemplars of G. velutinum, but not between G. heathii and G. nuciforme.

The final departure was retaining G. album in Gibbaeum. It will be seen from the near-final short matrices that the homogeneity value between G. album (2) and the centroid of all the other members of the genus (all but OTU's 11, 19 and 36) is, in fact, higher than that between G. album and any of the minor genera. The characters that are most different from the rest of the group are the structure of the tomentum, the lack of sculpture on the seeds and the relatively pale colour of the plant body in the field. In all other characters

there is at least one "core" Gibbaeum more extreme than G. album. It was also noted that in the group-forming run without size extraction, it was not G. album but G. pachypodium whose presence in the group was questionable.

4.3 Identifications and identification systems

One of the avowed aims of the present study is to produce one or more procedures leading to the accurate identification of any unknown specimen belonging to the present group. It was desired that such a specimen should be identified with the greatest possible accuracy and the least possible effort, regardless of the facilities available or the state of the specimen.

A wide variety of different manually operated identification systems have been proposed for use in biology (Leenhouts, 1966), as well as relatively few computer-aided systems (Morse, 1971). These include such apparently diverse systems as the seventeenth-century precursors of the indented dichotomous key described by Voss (1952) and the computer-aided system described by Morse, in which the computer interrogates the operator. All these techniques, however, belong to one or other of two groups: analytical keys, which have only one entry point, and polyclaves (this term, coined by Duke (1969), is used here in the wider sense given to it by Morse), which have many entry points.

Analytical keys are easily reproduced, being printed documents, and relatively easily optimised, the theory of optimisation having been worked out by Osborne (1963). A dichotomous key can be used with maximum efficiency if each step splits the remaining group of

taxa into two equal subgroups. In general, a polychotomous step with n branches at any point in an analytical key operates at maximum efficiency if it splits the group into n equal subgroups. This means that the mean path-length from the start of the key to the level at which an identification is achieved is minimised.

Attempts have been made (Morse 1971, 1974) to weight different taxa according to their relative commonness or rarity, so that common taxa are keyed out first, and to weight characters so that the easiest to observe are used preferentially. Taxon-weighting would tend to minimise the error-rate per unit time, on the assumption that the key will be used more often to identify common taxa than rarities. Character weighting tends to minimise the chance of using a difficult character near the start of the process, and so it minimises the possibility of trying the wrong major section of the key, and so it minimises the error-rate per identification.

Analytical keys do have their practical disadvantages, despite their clear theory and apparent simplicity. These are largely related to their single entry-point and limited number of paths to the correct identification.

The most frequently-encountered of these is that it is very difficult to construct a key that will enable one to identify an incomplete specimen unambiguously if it belongs to a large group, such as the Mesembryanthemaceae. Keys to the genera of this family

have been constructed both by Bolus (1958b) and Herre and Volk (Herre, 1971). Both of these require flowers and dry fruit for an identification, but very few members of the family have both at the same time.

Variable taxa present a problem to the constructor of analytical keys. If one allows for variation by allowing the taxon in question to key out in more than one place, then one degrades the overall efficiency of the key by lengthening it. If one allows for variation by describing it where it occurs in the key, then efficiency is degraded by basing a dichotomy on a property which is less than desirably clear, or by lowering the ease of observation.

The addition of taxa to an existing analytical key is a relatively severe problem, involving the re-writing of at least part of the key. If the additions are more than minor, it would probably be better to restart the key from the beginning, if optimisation is to be retained.

Ease of observation optimisation requires that a minimum of characters be used at each step. In fact, use of more than one character in a step implies that the characters used are not fully independent. Rypka et al. (1967) have shown that it is theoretically possible to construct a key to any number (T) of taxa using not more than n characters, where

$n = \log_2 T$, rounded up to the nearest integer.

In fact, considerably more than this minimum number are usually used, but the number of characters rarely exceeds the number of taxa. It may therefore happen that a highly

distinctive and potentially useful character, for example an accurate locality label, is present on the specimen but not used in the key.

Because of the highly structured nature of analytical keys, and because of the relatively small number of characters conventionally employed, it was decided that no single key could identify all specimens in the present group with equal optimality. Specifically, it was found by constructing keys using the BOLAID key-generating module, that a key optimised for herbarium use would probably be useless in the field. This probability was increased to a certainty if the state of the "minimum specimen" - assumed to be a pair of leaves and a capsule - was taken into account. For this reason two dichotomous keys, one for field use and one for herbarium use, are supplied. The former ignores epidermal characters as far as possible and the latter ignores locality data, while both make minimal use of flower characters as these are rarely available.

A polyclave has as many entry points as the number of characters used, and an effectively infinite number of pathways from the start to identification of the specimen. Very little skill is necessary to identify a plant using a polyclave, but the speed and accuracy of identifications improve with skill and knowledge of how they work.

Sneath and Sokal (1973) divide polyclave algorithms into simultaneous and sequential. The basic strategy of a simultaneous polyclave is to calculate the

value of one or another similarity function between the unknown specimen and all taxa in the identification matrix. The value of this function should be high with only one taxon, to which the unknown is assigned if the value is above a pre-determined threshhold. Alternatively, a taxon is considered to be a region in character hyper-space, and the locality of the unknown in this space is calculated. The unknown is assigned to a particular taxon if it falls into that particular region of the space. Typical simultaneous methods are those of Gyllenberg (1967) and Lapage et al. (1970, 1973).

In sequential polyclaves, characters are considered one at a time. In each step, a subset of taxa having the character in question in the same state as the unknown is extracted from the complete set, and compared with the subset resulting from the previous step. Those taxa common to both subsets form the set of possible identifications for the next step. When this set contains only one taxon, the unknown has been identified. A wide variety of such polyclaves has been described by Leenhouts (1966).

Essentially, they fall into three groups: printed, card and computer-operated, although the same polyclave may be converted from one form to another.

Printed polyclaves may be even cheaper to reproduce than the equivalent dichotomous key, because they can be compressed into less space. For example, Meyer's (1969) key to the families of flowering plants of South-West Africa, a polyclave, occupies about 220

lines, whilst Merxmuller's (1972) dichotomous key occupies about 1500 lines. In most cases, however, a polyclave is more expensive to reproduce.

A form of polyclave on plastic cards has been described (Leenhouts, 1966), but polyclaves on cardboard cards are far commoner. Most punch-card polyclaves fall into two groups: centre-punched, one card per character state; and edge-punched, one card per taxon. The former kind is exemplified by the keys of Bianchi (1931 - the first punch-card polyclave) and Hansen and Rahn (1969); the latter by Baker's (1970) key to Erica.

With the possible exception of computer-generated punch-card polyclaves, this kind of key is very expensive to reproduce, as accurate punching dies must be made for each card in the key. With computer-generated keys, standard 80-column cards are punched with a standard card punch, and in this way a punch-card key can be produced for a realistic price.

Edge-punched card keys can be operated with a mechanical card sorter or a skewer, but are more subject to damage than centre-punched cards. The latter, on the other hand, do not usually have any space for annotation.

On consideration of the various merits and demerits of different kinds of polyclave against each other and against analytical keys, it was decided to incorporate a polyclave into the present work. The polyclave is 'printed' in a general format (Morse et al. 1971) that allows it to be used in Morse's (1974) program package to produce dichotomous keys and punch-card

polyclaves, and to be used as the data base of a computer operated polyclave. Characters available include the herbarium set, the field set and some others that may only be available on more-than-minimal specimens.

4.3.1 Computers and identification

The role that a computer can play in an identification system is, of course, a function of that system. In an analytical-key system it is very different to the function in a polyclave system.

Because the construction of an analytical key is achieved by the operation of a defined algorithm on pre-standardised data, analytical keys can be constructed by computer. At present, there are five key-constructing programs (Gower and Barnett, 1971; Hall, 1972; Möller, 1962; Morse, 1974 and Pankhurst, 1970). Analytical keys are not suited to operation by computer.

Four out of the five key-generating systems (all except Gower and Barnett's) were available to the author for experimentation.

The use of the different computer key-forming systems with various forms of data highlighted one very important difference between key-forming and group-forming. This relates to the different actions of binary, multistate and modal properties in a matrix.

Properties with discrete states, i.e. binary and multistate data, have a divisive effect upon the results of a data manipulation (group-forming, key-forming etc.) involving such data. This is because

there are no allowed states between those assigned by the data capturer. For example, if petal colour is coded into the discrete states white, pink, magenta, ..., then there is logically no space for a plant whose petals are pale pink or deep pink, nor for a taxon in which petal colour is variable between white and deep pink. One may, however, design an identification-type (including key-forming) system to go around this problem.

Modal properties, on the other hand, are those which do not have discrete states but are continuously variable. These characters may not be as divisive in effect as "state" properties. For example, if petal colour is scored so that white petals are given the value 0, magenta petals the value 50, and pink petals an intermediate value related to the depth of colour present, then values such as 8,2, 39,37 and 70 would be meaningful, representing a particular pale pink, a particular deep pink and purple. Variability may be coped with in a variety of ways, such as citing a range, or mean and standard deviation or range and mean.

In manipulations such as group-forming, the effect of incorrectly assigned "state" properties is to produce spurious discontinuities (e.g. petals may be white or pink but not pale pink); intermediate states, variable properties or centroids between two or more OTU's with properties in different states show that discrete-state coding should not be used.

If one scores all properties in which intermediates are imaginable, regardless of whether they occur in the group in question, as modal (e.g., instead of the multistate "property", betalains as (1) betaxanthins, (2) betacyanins (3) both (4) absent, one scores two modal properties, percentage betalains as betaxanthins and percentage betalains as betacyanins) one is likely to find that very few if any characters are truly binary or multistate. Scoring as many properties as possible as modal - and there is a great likelihood that this will be all the properties used in a study - variability in characters will be represented with the greatest possible fidelity. Any discontinuities that are found, will be genuine, and unintentional weighting of characters will be held to a minimum at worst, or eliminated at best.

In identificatory manipulations such as key-forming, one seeks for clarity above all else. Here the problem of continuous or sub-continuous variation may be handled in two ways: one may seek another, more distinctive character, or one may allow a few items to fall on both sides of the division. If efficiency in these manipulations is to be maximised, it may be considered necessary either to label sub-continuous characters as undesirable (e.g., with a low convenience weighting) or recode such characters so that the sub-continuities appear as full continuity. This latter course may involve taking one or more modal characters

in a suite and recoding them as a suite of the same or a different number of binary or multistate characters.

It should be emphasised that the second course outlined above is suitable only for qualitative modal characters (e.g. flower colour as colour), not for quantitative modal characters (e.g. flower colour as concentrations of pigments, or leaf length).

If, as a result of such a manipulation, a taxon is scored as variable in an important state character, then it may be split manually or automatically into two OTU's, each having that character in a different state. Such a taxon will then key out in two different parts of the key.

The results of using a data matrix optimised for group-forming, in a key-forming run, are unpredictable. At best, one will produce an optimised key but lacking the extra convenience afforded by the data-feature noted above, and at worst, the system may be unable to produce a key. One may find that a key results, but that it is unworkable and that it was produced after an unrealistic amount of computing time.

Provided that one recognises the difference between an optimal group-forming matrix and an optimal identificatory matrix, and provided that one chooses a system that will accept the available kinds of data, the choice of an identification system is almost entirely a matter of personal preference. If one chooses group-

forming and identification packages that require data in very different formats, the chance of inadvertently using the wrong data matrix with each package is minimised. Even if one does select the wrong file inadvertently, a data error will probably be recorded and spurious results will not be produced.

The role of the computer in a polyclave system is usually that of operator, or occasionally that of transformer, rather than constructor, as the polyclave itself is little more than a data matrix - indeed, some computer data files may be used as polyclaves.

Computer-aided identification systems (automated polyclaves) are many, e.g. those of Boughey, Bridges and Ikeda, 1968; Goodall, 1968; Morse, 1974 and the simultaneous methods mentioned above. Each has its own advantages and disadvantages, but none of them can be used away from the collector's "home base". It is possible that with vast increase in the technology of miniaturisation in computing or long-distance communication with existing computers this may change, and then a discussion of the use of one system rather than another in the field would be more in order than it would be now.

5. KEYS

Because the range of characters available to the worker in the field is not the same as that available to the worker in the herbarium or laboratory, different keys for field and herbarium use are provided. The characters used in the polyclave are essentially those of both the dichotomous keys. This provides for the case where neither key may be completely satisfactory.

5.1 Polyclave

The data matrix of appendix 3 in the code of Morse et al. (1971) may be used as a polyclave in two different ways.

The simpler method is a modification of Newell's (1970) tabular keys and Meyer's (1969) polyclave. One requires a pencil and a piece of scratch paper, on which one writes a list of possible taxa (initially, all 19), coded by number, as in the first part of the matrix. Characters are then selected in order of decreasing convenience, deleting taxa that are inconsistent with the description until only one is left. The one remaining is the desired identification.

If many identifications are to be undertaken, it may be worth while to convert the polyclave to a punch-card key (cf. Hansen and Rahn, 1969). This can be done by computer (Morse, in press; Pankhurst, pers. comm.) or manually, for which purpose IBM "Port-a-Punch" cards will be found well suited, being relatively cheap,

easily available and pre-scored for punching. One card is allotted to each state of each character, and positions on the card are allotted to taxa in any way convenient to the user. Taxa recorded in the matrix as variable for any character are scored as positive for both or all the relevant states of that character. Quantitative characters are divided into states at the discretion of the user.

The method of scoring characters in the matrix, published by Morse, Peters and Hamel (1969), is reproduced below for convenience.

Binary characters:
0 = unknown
1 = positive
2 = variable
3 = negative
4 = irrelevant

Multistate:
0 = irrelevant
1 = state 1
2 = state 2
4 = state 3
8 = state 4
16 = state 5
32 = state 6
-9 = unknown

Characters which may assume more than one state are scored as the sum of the scores of the relevant states, thus variable over states 1, 3 and 4 would be scored as 1 + 4 + 8 = 13.

Quantitative characters are scored as minimum and maximum, each value being 3 digits long, the value being expressed as a decimal thus: 111.hhh (example: range 15 - 40 is written 015.040,). Irrelevant characters are scored as 000.000 and unknowns as -99.999 .

5.2 Field key

Flower characters are used as accessories only. This key assumes the availability of intact capsules and a hand-lens.

1. Leaves keeled:

    2. Leaves roughly as wide and deep as long - hemispherical to roughly tetrahedral:

        3. Plants hairy:

            4. Plant found in the Little Karoo (Springfontein, Brand River); flowers white or pink... Gibbaeum album

            4'. Plant found South of the Langeberg (Bredasdorp, Swellendam and Heidelberg Divisions); flowers deep pink to magenta..... G. austricolum

        3'. Plants glabrous:

            5. Peduncles lateral, bracteate; bracts conspicuous, appearing long before the flowers, always in pairs; flowers pale pink, found in the Ceres Karoo Didymaotus lapidiformis

            5'. Peduncles terminal, ebracteate, solitary; flowers magenta, found in the Little Karoo..... G. petrense

    2'. Leaves triquetrous - significantly longer than wide or deep:

        6. Plant found South of the Langeberg (Bredasdorp, Swellendam and Heidelberg Divisions); flowers deep pink to magenta..... G. austricolum

        6'. Plant found in the Little Karoo (? or the Robertson Karoo); flowers white, pink or magenta

            7. Leaves symmetrical - transverse section an equilateral triangle:

                8. Leaves emerald green; plants forming large mats ca. 1 m. or more in diameter; found at Muiskraal, flowering in July G. angulipes

                8'. Leaves grey-brown in drought or dive green after rain, forming clumps up to ca. 60 cm. in diameter; found at Ockertskraal, flowering in December G. pachypodium

7'. Leaves flattened - transverse section an inverted isosceles triangle with the depth much longer than the width of the leaf:

9. Leaves glabrous, plants found in the Robertson Karoo near Stormsvlei; flowers magenta..... G. esterhuyseniae

9'. Leaves hairy; plants found from Barrydale to Sandkraal; flowers white to magenta..... G. velutinum

1'. Leaves not keeled:

10. Leaves digitiform - significantly longer than wide or deep:

11. Plants hairy:

12. Leaves brown during drought but olive green after rain, rarely over 20 mm long; plant with creeping branches; from the Touwsberg to Warmwaterberg G. geminum

12'. Leaves silvery, glaucous, apple green, deep green, yellow-green or rarely reddish but not brown or olive green, rarely less than 20 mm long; plant forming small clumps or bushes, widespread:

13. Hairs simple and reflexed; leaves relatively long and thin, silvery to glaucous; widespread G. pubescens subsp. pubescens

13'. Hairs stellate and erect; leaves broader and shorter, apple green, deep green, yellow-green or rarely reddish; restricted to part of the Kareevlakte and Hondewater G. pubescens subsp. shandii

11'. Plants glabrous:

14. Pedicles ebracteate; one leaf of a pair much longer than the other; top of the capsule nearly flat; seeds not echinate; cell membranes entire..... G. gibbosum

14'. Pedicels bracteate; leaves of a pair more or less the same size; top of the capsule arched; seeds echinate; centre of the cell membrane split to the base
Antegibbaeum fissoides

10'. Leaves roughly hemispherical - about as long as wide and deep:

15. Leaves not connate as far as the tip, or fissure extending the full width of the plant body:

16. Capsules (7 -) 8 (- 10) -locular; plants glabrous; flowers white, rarely pale pink or, in one locality, deep pink; widespread, variable in shape, size and colouring... G. heathii

16'. Capsules 6 (- 7) locular; plants hairy; flowers pink to magenta:

17. Leaves above the level of the ground; plants found at Vanwyksdorp or Springfontein:

18. Leaves brown, plants usually found on shale, flowers pink
G. dispar

18'. Leaves glaucous, silvery or green, plants always found on quartz, flowers magenta, plants very variable
X Muiriogibbaeum muirioides

17'. Leaf apices at ground level even after good rains, leaves deep green; plants usually found in shale at Kareevlakte and Dammetjies..... G. nebrownii

15'. Fissure less than half as long as the width of the plant body, or absent:

19. Fissure present; plants widespread; capsules with cell membranes and valve wings:

20. Plants hairy.... G. pilosulum

20'. Plants glabrous. G. nuciforme

19'. Fissure absent; from Springfontein; capsules without cell membranes and valve wings..... Muiria hortenseae

5.3 Keys for Herbarium use

These keys assume the availability of one pair of leaves and a capsule with peduncle in good condition; flower characters are excluded as flowers in good condition are rarely found in herbarium specimens. Either a dissecting microscope with the capability of magnifying fifty times or more, or a cuticle preparation (method, appendix 6) will be needed to identify a specimen using these keys.

5.3.1 Key to the Genera

1. Peduncles with bracts:
    2. Leaves digitiform, seeds echinate, tops of the capsules arched..... Antegibbaeum
    2'. Leaves tetrahedral, seeds not echinate, tops of the capsules nearly flat..... Didymaotus

1'. Peduncles ebracteate:
    3. Leaves connate to the apices, without any fissure; capsules without covering membranes and valve wings..... Muiria
    3'. Leaves variously connate, but a fissure always present; capsules with covering membranes and valve wings..... Gibbaeum

5.3.2 Key to the species of Gibbaeum

1. Leaves about as long as wide and deep (hemispherical to tetrahedral):
    2. Plants hairy:
        3. Trichomes simple:
            4. Epidermal cells of two different sizes..... G. pilosulum
            4'. Epidermal cells all about the same size..... G. austricolum

3'. Trichomes branched:

5. Trichome branches interlocking
G. album

5'. Trichome branches not interlocking:

6. Trichomes branched near the apices; larger sepals less than 4,5 mm long..... G. dispar

6'. Trichomes branched at midway of their total length; larger sepals ca. 6 mm long..... G. nebrownii

2'. Plants glabrous:

7. Capsule (7 -) 8 (- 10) locular
G. heathii

7'. Capsule 6-locular:

8. Epidermal cells of two different sizes; leaves connate nearly to the apices; body with a short fissure
G. nuciforme

8'. Epidermal cells all about the same size; leaves connate for less than half of their total length, bodies with a fissure extending the full width of the body
G. petrense

1'. Leaves triquetrous or digitiform:

9. Epidermal cells of two different sizes:

10. Plants glabrous..... G. gibbosum

10'. Plants hairy:

11. Hairs simple..... G. pachypodium

11'. Hairs branched..... G. velutinum

9'. Epidermal cells all about the same size:

12. Plants glabrous..... G. esterhuyseniae

12'. Plants hairy:

13. Trichomes simple:

14. Both leaves of a pair more or less the same size.... G. austricolum

14'. One leaf of a pair much larger than the other... G. pubescens subsp. pubescens

13'. Trichomes branched:

15. Both leaves of a pair more or less the same size.... G. angulipes

15'. One leaf of a pair much larger than the other:

16. Leaves rarely more than 20 mm long; epidermal cells less than 65 in greatest diameter; petals 30 or less; larger sepals less than 6 mm long G. geminum

16'. Leaves rarely less than 20 mm long; epidermal cells more than 85 in greatest diameter; petals ca. 60; larger sepals ca. 9,5 mm long G. pubescens subsp. shandii

6. TAXONOMIC TREATMENTS

Note: Measurements with three values (nnn - nnn - nnn) are in the form minimum - mean - maximum. Where only two values are given, they are minimum and maximum. A single value is a mean. Means are not given unless they differ from the value (minimum + maximum)/2 by more than 10% of the range of values.

The following abbreviations are used to indicate the states of specimens cited:-

fl. - at least one flower present

fr. - at least one fruit present

nf. - neither flowers nor fruit present

6.1 G I B B A E U M

Gibbaeum (Haw.) N.E. Br., Gard. Chron. 70:273 (1921); N.E. Br., Gard. Chron. 71: 129, 151 (1922); Tischer, Z. Sukk. 2:116 (1925), N.E. Br., Gard. Chron. 78:413, 433 (1925); Phill., Gen. S. Afr. Fl. Pl. ed. 1 :242 (1926); N.E. Br., Gard. Chron. 79:172 (1926); Tisch., Z. Sukk. 3:227 (1927); L. Bol., Notes Mes. Allied Gen. 1:45 (1928); N.E. Br., Tisch., Karsten, Mesembryanthema :31 (1931); Jacobsen, Sukk. Pfl.:132 (1933); Von Pöllnitz, Feddes Rep. 33:43 (1933); Pax & Hoffmann, Natürl. Pflanzenfam. ed. 2 16c:215 (1934); Jacobsen, succ. pl. :178 (1935); Tisch., Kakt. u.a. Sukk. 1937: 150 (1937); Goossens, Blompl. :143 (1940); Phill., Gen. S. Afr. Fl. Pl. ed. 2 :304 (1951); Nel, The Gibbaeum Handbook :22 - 24 (1953); Jacobsen, Handb. Succ. Pl. 3:1148 (1960); Jacobsen, Sukk. Lex. :425 (1970); Herre, Gen. Mesemb. :162 (1971)

Mesembryanthemum L. sect. Gibbaeum Haw., Rev. Pl. Succ. : 104 (1821)

Mesembryanthemum L. sect. Gibbosa Haw., Syn. Pl. Succ. :226 (1812); Don, Gen. Syst. Gard. Bot. 3:131 (1834); Sond., Fl. Cap. 2:404 (1862); Berger, Mesembryanthemen und Portulacaceen : (1908)

Mesembryanthemum L. sect. Abbreviata Haw., Misc. Nat. :36 (1803)

Mesembryanthemum L. sect. Inaequifolia gibbosa Salm Dyck, Obs. Gen. Aloes Mesemb. : 18

Argeta N.E. Br., Gard. Chron. 82: 113 (1927); N.E. Br., Jl. Bot. 66:265 (1928); Tischer, Monatsschr. D. Kakt. Ges. 1:234 (1929); N.E. Br., Tisch., Karsten, Mesembryanthema :258 (1931); Jacobsen, Sukk. Pfl. :90 (1933); Von Pöllnitz, Feddes Rep. 33:26 (1933); Jacobsen, Succ. Pl. :225 (1935); Goossens, Blompl. :146 (1940)

Imitaria N.E. Br., Jl. Bot 65:348 (1927); N.E. Br., Tisch., Karsten, Mesembryanthema :239 (1931); Von Pöllnitz, Feddes Rep. 33:46 (1933); Jacobsen, Sukk. Pfl. :141 (1933); Jacobsen, Succ. Pl. :190 (1935); Jacobsen, Verzeichnis :94 (1938); Goossens, Blompl. :147 (1940); Schw., Fl. Stones :172 (1957); L. Bol., Notes Mesemb. Allied Gen. 3:388 (1958); Jacobsen, Handb. Succ. Pl. 3:1182 (1960); Jacobsen, Sukk. Lex. :434 (1970); Herre, Gen. Mesemb. :178 (1971)

Mentocalyx N.E. Br., Gard. Chron. 81:251 (1927); N.E. Br., Tisch., Karsten, Mesembryanthema :258 (1933); Von Pöllnitz, Feddes Rep. 33:49 (1933); Goossens, Blompl. :147 (1940)

Rimaria N.E. Br., Gard. Chron. 78:413 (1926) (in clav.); N.E. Br., Gard. Chron. 79:85, 134 (1927); Tischer, Z. Sukk. 3:226 (1927); N.E. Br., Gard. Chron. 81:85 (1929); West, Jl. Cact. Succ. Soc. Amer. 1:207 (1930); Jacobsen, Sukk. Pfl. :173 (1933); Von Pöllnitz, Feddes Rep. 33:64 (1933); Jacobsen, Succ. Pl. :240 (1935); Goossens, Blompl. : 147 (1940)

Type species: G. pubescens (Lettsom ex Haw.) N.E. Br.

Plants forming cushions or mats, or dwarf succulents; internodes very short, hidden by the leaves; leaves opposite, sometimes decussate, perfoliate-connate at the base, more often connate to form a sheath, rarely connate to the apices or almost to the apices; triquetrous to semiterete, sometimes very gibbous, sometimes hardly gibbous, one leaf almost always longer than the other in each pair, 3 - 175 mm long, 3 - 55 mm in diameter (depth in triquetrous-leaved species). Rootstock fibrous or stout and woody.

Indumentum present or absent, when present, composed of simple to much-branched hairs, these erect to appressed. Epidermal cells either all about the same size or of two different size ranges, if the latter, then the larger cells bearing the trichomes in species where these occur, these always unicellular; epidermal cell walls straight to curved or rarely undulate. Leaf surface white, pale grey, glaucous, pale to emerald green (the latter in cultivation), reddish, yellowish-green or brown.

Flowers solitary. Peduncle ebracteate; sepals 6, 7 or 8, in two whorls, the outer ones often larger

than the inner, sometimes all the same size, when of different sizes, the inner usually flat with membranous margins and the outer triquetrous or semiterete. Outer sepals 3,8 - 23,9 mm long and 1,7 - 10 mm wide, the inner 3,8 - 12,5 mm long and 1,4 - 9 mm wide, green, some with tanniniferous idioblasts irregularly arranged, vestiture as for the leaves. Petals 20 - ∞ , lorate to spatulate, white, pink, magenta or purple, 6 - 29 mm long, 0,6 - 2,2 mm wide at the widest point, 1 - 4 -seriate. Staminodes present or absent, when present usually with the appearance of an antherless filament, rarely a small petal or intermediate between these, 0 - 100 in number, white or the same colour as the petals, size intermediate between the filaments and the petals. Stamens 18 - 250, filaments usually white, rarely yellow, 1 - 12 mm long, the longest near the petals or staminodes, the shortest near the ovary, erect; anthers and pollen yellow. Ovary usually 6-, sometimes 8-, rarely 7- or 9-locular, inferior, styles 6 - 8, subulate or feathery, free to the base; stigmas longitudinal on the inner side of the style; placentation parietal, ovules many. Capsules (5 -) 6 - 8 (- 10) locular, with cell lids and valve wings, without placental tubercles, loculicidal, hygrochastic. Seeds pale to deep brown or maroon-brown, ovoid, with a prominent funicle, testa variously patterned, not echinate, 0,4 - 1 mm long. Pollen grains ovoid or ellipsoidal, tricolpate, polar diameter ca. 13 u, equatorial diameter ca. 11 u.

Species 15, with 1 subspecies.

Sectio 1. Macrogibbaeum Glen, sect. nov.

Macrogibbaeum Glen, sect. nov, e partibus sectionum Imitariopsis Wulff et Mentocalyx (N.E. Br.) Wulff composita.

Plantae succulentae, pro ratione largae. Folia longa, triquetra, sectioni transverse aequilaterale triangularis, viridia vel brunnescentia. Indumentum confertum, trichomata simplicia vel semel dichotome ramescentia. Flores rosei vel magentei.

Species duo: G. pachypodium et G. angulipes.

Plants relatively large succulents, forming large clumps or mats; leaves long, triquetrous, equilateral-triangular in transverse section, green to brownish. Indumentum dense, trichomes simple or once dichotomously branched.

Flowers pink to magenta.

Species two: G. pachypodium and G. angulipes

1. Gibbaeum pachypodium (Kensit) L. Bol., Notes Mesemb. allied Gen. 1:152 (1928); Nel, Gibbaeum Handb. :94 - 97 (1953); Jacobsen, Handb. succ. Pl. 3:1155 (1960); et in Sukk. Lex. :426 (1970)
Mesembryanthemum pachypodium Kensit, Trans. Roy. Soc. S. Afr. 1:152 (1900); H. Bol., Feddes Rep. 12: 322 (1913)

Holotype: "Between Mistkraal and Ladismith", 1906, fl. Pillans 892 (BOL!)

Plants forming clumps up to 60 cm in diameter, but often of irregular shape; each stem with two or more leaf pairs. Leaves opposite, trigonous to terete, one of a pair somewhat larger than the other, larger leaf 60 - 100 mm long, 5 - 15 mm wide and deep, the lesser 25 - 60 - 80 mm long, 4 - 8,5 - 10 mm wide and deep; burnt siena to grey-green in colour, moderately to sparsely pubescent. Epidermal cells of two distinct sizes, the larger hexagonal to octagonal or irregular, 69 - 80 microns in diameter, with straight walls and a long, straight to slightly curved hair with walls without any involutions; remainder of the outer surface without sculpturing or with small dots or short fine lines; smaller cells rectangular to hexagonal, or rarely octagonal with four sides much shorter than the other four, 31 - 44,5 microns in diameter, without hairs, outer wall sculptured with small dots and fine short lines; stomatal ratio 6%, stomatal aperture 21 - 22 microns long, guard cells 42 microns long, 7 microns wide, subsidiary cells 2 per stoma. Rootstock stout and woody.

Flowers solitary, 42 mm in diameter, peduncle 60 mm long, 5 - 8 mm in diameter, ebracteate; sepals 6, two large and fleshy, the others smaller with membranous margins, the larger sepals up to 24 mm long and 7,2 mm wide, the lesser ones up to 11 mm long and 8,5 mm wide; petals 49 - 90, biseriate, 14 - 18 - 20 mm long, up to 1,4 mm wide, pale to deep pink; staminodes 40 - 60, 4 - 8 - 14 mm long, white; stamens 80 - 120, filaments 4 - 5,4 - 8 mm long; styles and stigmas 6, narrowly subulate, 1,2 - 4 - 7,5 mm long. Capsule 6-locular, 10 mm in

diameter. 7 mm deep, campanulate; seeds pale to mid-brown 0,95 - 1,00 mm long, 300 - 600 microns wide, 500 - 600 microns deep, funicle 200 - 300 microns long; surface pattern of close-packed, elongate humps, grading to irregular, tessellate elements away from the funicle; funicle pattern elements rectangular to irregular, close packed. Chromosome number : 2n = 18 (de Vos, 1951) or 36 (Wulff, 1944).

Specimens seen

CAPE: 3321; -AD, nr. Ladismith, 7 October 1932, bud, Jordaan 6 (BOL) Ladismith, 27 November 1928, fl., P. Ross Frames s.n. in NBG 2559/27 (BOL)

-CA, between Mistkraal and Ladismith, 1906, fl., Pillans 892 (BOL, holotype); Ockertskraal, 14 October 1973, fr., Glen 708 (BOL)

-C , Langeberg, Riversdale Division, Dec. 1927, fl., Compton and Lamb s.n. in NBG 2362/27

The type sheet appears to have three gatherings on it. The first of these consists of four fragments, each of them a leafy branch. Three of these have flowers, one a bud and one a portion of the rootstock. There is an unmounted dissected flower in a capsule in this gathering. The label is in pencil, in Pillans' handwriting. The second gathering consists of one fragment with two capsules and an unmounted half-flower. The label of this gathering states that it was flowered "in Mr. N. S. Pillans' garden.....". The third gathering consists of two flowering fragments without a label. There is a rough pencil drawing of a live plant attached to the sheet.

The present species has long, symmetrical, triquetrous leaves like those of G. angulipes, but does not form large mats, rather it forms spreading clumps covering a much smaller area. It has much longer peduncles and outer sepals than any other member of the group. It flowers in December and grows on white quartz patches on lower hill slopes or plains in the central Little Karoo. It is relatively rare, and recent road construction near a known locality of this species could be interpreted as a danger to it.

The specific name is derived from Greek words meaning "broad-based", referring to the leaves.

2. Gibbaeum angulipes (L. Bol.) N.E. Br., Gard. Chron. 81:430 (1927); Tischer, Z. Sukkulentenk. 3:227 (1927); Nel, Gibbaeum Handbook :98 - 101 (1953); Jacobsen, Handb. Succ. Pl. 3:1151 (1960); et in Sukk. Lex. :425 (1970)

Mesembryanthemum angulipes L. Bol., Ann. Bol. Herb. 4:2 (1925)

Holotype: Klein Karoo, Riversdale Div., 1000 - 1300 ft., fl. Sept. and Oct., Muir 3398 (K!)

Plants forming mats one to several metres in diameter; each branch usually with two pairs of leaves at a time; leaves opposite, distinctly triquetrous, the larger leaf of a pair 21 - 37 mm long and 6 - 7,5 - 10 mm on a side, the smaller 17 - 21 - 30 mm long and 5 - 10 mm

on a side, bright green or yellow-green, varying in one population. Indumentum of hairs projecting from each epidermal cell except the guard cells and subsidiary cells of stomata; hairs usually dichotomously branched, the branches of the first dichotomy as long as the main hair and one or both often dichotomising again, the secondary branches very short; rarely one arm of the first dichotomy overtopping the other and then with short side branches, the minor arm appearing as a side branch. Epidermal cells uniform, hexagonal, 58 - 72 microns in diameter, walls somewhat bowed, outer wall fairly heavily sculptured with lines; stomatal ratio 9,5%, stomatal aperture 19 microns long, guard cells 34 microns long and 8,5 microns wide, subsidiary cells 2 - 4 per stoma. Rootstock moderately stout and woody.

Flowers solitary, ca. 25 mm in diameter; peduncle ebracteate, 22 mm long, 3 - 4 mm in diameter; sepals 6, two somewhat longer than the rest, these 5 - 7 mm long, the others 4,5 - 6 mm long, all ca. 2,5 mm wide; petals biseriate, 9 - 12 mm long, 1 mm wide, magenta; staminodes absent, stamens many, filaments 2 - 3 mm long styles and stigmas 6, subulate, papillate at the base, 0,6 - 1,2 mm long. Capsule 6-locular, 4 mm in diameter, 3,5 mm deep; seeds deep reddish-brown, 630 - 870 microns long, 450 - 620 microns wide and 330 - 460 microns deep; surface pattern of discoid to cylindroconical elements, 10 - 13 microns in diameter, and ca. 14 microns apart; funicle 160 - 320 microns long; pattern of close-packed roughly rectangular to discoid elements. Chromosome number 2n = 18, 36 (Wulff, 1944; de Vos, 1951).

Specimens seen

CAPE: 3321; -CC, Muiskraal, 19 May 1973, fr., Glen 634 (BOL); Muiskraal, 19 May 1973, fr. Glen 635 (BOL); between Mistkraal and Ladismith, April 1925, fl., Muir 3898 (K, holotype)

Garden specimens: Riversdale Div., Oct. 1923, fl., Muir s.n. in BOL 17695 (BOL, holotype of synonym); Stellenbosch, Oct. 1932, fl., Anon. s.n. in SUG 9382 (BOL), Wynberg, Oct. 1926, fl., Muir s.n.; no locality, Nov. 1928, Muir s.n.

The type specimen consists of five fragments, one of which has a flower on it. There is also a capsule containing a dissected flower. The specimen has two labels, one in Muir's handwriting, and the other, in N.E. Brown's, indicating that it is the type.

The plants form large mats, which may be virtually continuous over a large area in a dense population, on white quartz patches. The leaves of a single population may be grass-green, yellow-green or any intermediate hue, and in shape they are long and narrow, like those of G. pachypodium but about half the size of these. The trichomes on the leaves are somewhat variable in that they are either branched twice dichotomously or they are asymmetrically branched, with one branch overtopping the other.

The specific name appears to be derived from two Latin words meaning "curved-base". This could refer to the distinct angle between the free part of the leaf and the leaf-sheath. No indication of the exact derivation of the name was given in the original description.

2. Mentocalyx

Mentocalyx (N.E. Br.) Glen, stat. nov.

Mentocalyx N.E. Br., Gard. Chron. 81: 251 (1927), pro gen.; N.E. Br., Tisch., Karsten, Mesembryanthema :258 (1931); Von Poellnitz, Feddes Rep. 32:49 (1933); Goossens, Blompl. :147 (1940)

subsect. Mentocalyx (N.E. Br.) Mulff, Bot. Archiv 45:167 (1944); Jacobsen, Handb. Succ. Pl. 3:1149 (1960); Jacobsen, Sukk. Lex. :425 (1970)

Type species: G. velutinum (L. Bol.) Schwantes

Plants forming small clumps; leaves large, usually the larger of each pair with a more or less prominently hooked apex; indumentum present or absent in one species, one specimen of this glabrescent, when present, the hairs dichotomously branched at half their length, sometimes branched again near the apices. Epidermal cells sometimes of two different sizes, sometimes all about the same size. Rootstock stout and woody.

Flowers large, terminal, solitary; petaloid staminodes white to magenta.

Two species, G. esterhuyseniae and G. velutinum.

3. Gibbaeum velutinum (L. Bol.) Schwantes, Z. Sukkulentenk. 3:106 (1927); Tisch., Z. Sukkulentenk. 3:227 (1927); Jacobsen, Succ. Pl. :181 (1935); Tisch. Kakt. und andere

Sukk. 1937:152 (1937); Jacobsen, Feddes Rep. 43:227 (1938); Nel, Gibbaeum Handb. :102 - 105 (1953); Jacobsen, Handb. Succ. Pl. 3:1157 (1960); Jacobsen, Sukk. Lex. :427 (1970)

Mesembryanthemum velutinum L. Bol., Ann. Bol. Herb. 3:124 (1922) Anon. s.n. in BOL 15195, holotype.

Mentocalyx velutina (L. Bol.) Schwant., Monatsschr. D. Kakt. Gess. 1:17 (1929); N.E. Br., Kew Bull. 1929 :57 (1929); N.E. Br., Tisch. Karsten, Mesembryanthema :258 (1931)

M. muirii N.E. Br., Gard. Chron. 81:252 (1927); Jacobsen, Sukk. Pfl. :133 (1933) Phisantefontein, 22 October 1926, fl., fr., Muir 3892 (K!, holotype; BOL! isotype)

G. muirii (N.E. Br.) Schwant. ex Jacobsen, Succ. Pl. :180 (1935), nom. illegit., non N.E. Br. (1926)

G. schwantesii Tisch., Kakt. und andere Sukk. 1937 :152 (1937); Nel, Gibbaeum Handb. :106 (1953); Jacobsen, Handb. Succ. Pl. 3:1156 (1960); Jacobsen, Sukk. Lex. :426 (1970) Muir 3892, holotype.

Holotype: cultivated plant, Kirstenbosch, no date, fl., Anon. s.n. in BOL 15195 (BOL!)

Small succulents forming clumps to ca. 60 cm in diameter; each branch with one to three pairs of leaves; leaves opposite, one much longer than the other, triquetrous, flattened vertically so that the transverse section is shaped like an isosceles triangle, the abaxial surface of the longer leaf longer than the

adaxia-, forming a "chin" or hook of varying distinctness; the larger leaf 35 - 90 - 175 mm long, and 9 - 26 mm deep; the lesser leaf 20 - 75 mm long and 9 - 13 - 24 mm deep, leaves grey-green, deep olive green to emerald green, or partly reddish. Indumentum of thick hairs branching dichotomously once about halfway from the base to the apices and sometimes once or twice more near the apices, on the large cells only. Epidermal cells often of two size ranges, otherwise the smaller cells almost as large as the larger cells or rare; smaller cells usually rectangular, pentagonal or irregular, 27,5 - 57 microns in diameter; the larger cells 5 - 7-sided, 50 - 80 microns in diameter; radial walls of all cells straight or slightly curved, outer walls heavily sculptured with dots; stomatal ratio 9 - 17%, stomatal aperture 13 - 18 microns long, guard cells 24,5 - 28,5 microns long and 3 - 7,5 microns wide; subsidiary cells 2 per stoma. Rootstock stout and woody.

Flowers solitary, up to 41 mm in diameter; peduncle ebracteate, up to 39 mm long and 2 - 8 mm in diameter; sepals 6, two much larger than the rest, the larger ones up to 14 mm long and 8 mm wide, the rest up to 8,5 mm long and 7,5 wide, the larger ones deltoid, the rest oblong-deltoid; petaloid staminodes 60 - 70, white to deep pink, - pale magenta, lorate to spatulate, 14 - 19 - 29 mm long and up to 1,6 mm wide, triseriate; non-petaloid staminodes absent or up to 50, 3 - 8 mm long;

stamens 125 - 250, filaments 3 - 8 mm long; styles and stigmas 6, reniform to subulate, 0,8 - 3,6 mm long. Capsule 6-locular, pale buff, ca. 9,5 - 11,5 mm in diameter and 6 - 8,5 mm deep; seeds pale brown to reddish brown, 775 - 1155 microns long, 445 - 620 microns wide and 480 - 660 microns deep, with a 210 - 460 u long funicle; surface pattern of hemispherical to elongate or irregular elements, in longitudinal rows or scattered irregularly, 25 - 39 - 59 microns in diameter, 6 - 7 microns apart, sometimes with a superimposted pattern of minute humps and furrows; funicle pattern of triangular to pentagonal or irregular elements in longitudinal rows, 20 - 40 mm in diameter, 0,5 microns apart; wax present in minute quantities on the seed surface. Chromosome number 2n = 36 (Wulff, 1944; de Vos, 1951)

Specimens seen

CAPE: 3320; -DC, near Barrydale, November 1956, nf., Hall s.n. (BOL); 1 mile from Barrydale, 5 October 1948, fl., Kramer 242 (BOL, PRE); Barrydale, 19 May 1973, fr., Glen 640 (BOL)

-DD, Klein Doorn Rivier, 12 April 1927, fr., Muir 3872 (K)

3321; -CC, Phisantefontein, November 1948, fl., Nel s.n. (BOL); Muiskraal, October 1936, fl., Rider s.n. in NBG 2958/34 (BOL); Muiskraal, 14 January 1948, fr., Compton 1041/47 (BOL); Phisantefontein, 22 October 1926, fl., fr., Muir 3892 (BOL, K, holotype of G. schwantesii);

Phisantefontein, 6 August 1926, nf., Ferguson 6 (BOL); Springfontein, May 1932, fl., L. Bolus s.n. in NBG 705/32 (BOL, K); east of Springfontein, 8 November 1971, fl., Wisura 2088 (NBG); Phisantefontein, 19 May 1973, fr., Glen 643 (BOL)

Storms Vlei is Aa

3420; -AC, Storms Vlei, February 1955, nf., Herre s.n. (BOL)

Without locality: Little Karoo, May 1932, fr., L. Bolus s.n. in NBG 710/32 (BOL)

Garden material: Stellenbosch, 7 November 1938, fl., Luckhoff s.n. in SUG 9888 (BOL); Kirstenbosch, no date, fl., Anon. s.n. in BOL 15195 (BOL, holotype)

Spirit material: without locality, 19 October 1948, fl., Anon. s.n. in STE-U 657 (STE-U)

No character can be used to separate G. velutinum sensu stricto from G. schwantesii; both hooked and non-hooked leaves are found in both taxa; a large plant of the former is as large as a small plant of the latter; hairs with more than one dichotomy are found in the former, and all other characters show either overlapping ranges or the range of one alleged taxon included in the range of the other. Therefore, it seems advisable to unite the two into one taxon which is natural, if somewhat variable.

The large, variable taxon which results from the union of the two former species is instantly distinguishable from any other species that grows near it

by the triquetrous leaves, which are several times the size of those of any species in the vicinity. The dichotomously branched hairs are distinctive on herbarium specimens, and can be seen under a high-power (50X or more) dissecting microscope as well as, if not more clearly than in a Stace preparation.

Flowers of G. velutinum may be pink or white, and flower colour shows no correlation with other characters, although it has been suggested as a distinguishing character of supposed species. G. velutinum flowers in October and November.

This species is found on white quartz patches or rarely on yellow to pale brown sand, at the foot of the northern foothills of the Langeberg, from Barrydale to Sandkraal.

The type consists of a dissected flower, a painting of a whole, flowering plant and handwritten notes in L. Bolus' handwriting. Although the label does not indicate its status, it is the only item in the Bolus Herbarium which bears the accession number cited in the published protologue.

4. Gibbaeum esterhuyseniae L. Bol., Notes Mesemb. allied Gen. 3:327 (1958); Jacobsen, Handb. Succ. Pl. 3:1152 (1960); Jacobsen, Sukk. Lex. :426 (1970)

Holotype: between MacGregor and Storm's Vlei Kloof, 12 October 1940, fl., fr., Esterhuysen 5655 (BOL!)

Small succulents forming clumps to c. 50 cm in diameter; each branch with one to three pairs of leaves; leaves opposite, one longer than the other, triquetrous, some leaf-apices distinctly hooked, larger leaf 27 - 50 mm long and 9 - 19 mm deep, lesser leaf 20 - 45 mm long and 8 - 16 mm deep, emerald to olive green. Indumentum absent. Epidermal cells hexagonal, 25 - 40 u in diameter, radial walls straight to slightly curved, outer wall usually without sculpturing; stomatal ratio ca. 7,5%, stomatal aperture ca. 13,5 u long, guard cells ca. 27,5 u long and 6,5 u wide; subsidiary cells 2 per stoma. Rootstock stout and woody.

Flowers solitary, up to 40 mm in diameter; peduncle ebracteate, up to 24 mm long and 4 - 6 mm in diameter; sepals 6, the two outer ones much larger than the others, up to 11,5 mm long and 3 mm wide, the inner sepals up to 7 mm long and 2,5 mm wide; petaloid staminodes 50 - 60, pink, lorate to spatulate, 10 - 22 mm long and up to 2 mm wide, triseriate; nonpetaloid staminodes absent or up to 50, 3,5 - 5 mm long; stamens ca. 100, filaments 3,5 - 5 mm long; styles and stigmas 6, subulate, 1,5 - 2,5 mm long. Capsule 6-locular, grey, ca. 10 mm in diameter and 4 mm deep; seeds red-brown, 485 - 745 u long, 270 - 425 u wide and 265 - 400 u deep, with a 120 - 300 u long funicle; surface patternor irregular elements, scattered irregularly, often interlocking, ca 25 - 52 u in diameter, up to ca. 3 u apart; funicle pattern of similarly irregular, or triangular to pentagonal elements, irregularly scattered, 14 - 25 u in diameter and usually close-packed.

Specimens seen

CAPE: 3419; -BB, between MacGregor and Stormsvleikloof, 12 October 1940, fl., fr., Esterhuysen 5655 (BOL, holotype)

3420; -AA, between Bonnievale and Stormsvleikloof, May 1951, Thudichum s.n. in BOL 26220 (BOL); Stormsvleikloof, February, 1940 Meiring s.n. in BOL 11428

Without precise locality: Little Karoo, October 1951, fl., L. Bolus s.n. (BOL)

This species appears to be extinct, as an exhaustive search of the area in which it is said to occur, yielded only specimens of Ruschia spp. If rediscovered, it would appear to be intermediate between G. velutinum and G. gibbosum. The hypothesis that it is a hybrid between these two species, possibly escaped from a succulent nursery that used to operate at Bonnievale, is rejected for two reasons. Firstly, neither supposed parent species is known from the area, and secondly although specimens of Gibbaeum have been in cultivation both at the Karoo Gardens, Worcester and at Kirstenbosch for at least thirty years, no self-seeded plants have been recorded at either garden.

This species was found on white quartz patches in a triangular area bounded by MacGregor, Bonnievale and Storm's Vlei, and used to flower in October.

The type of this species is on two sheets, bearing the same collecting number. On the first are

eleven fragments, one of them fruiting, and a capsule containing a fruit and a dissected flower. Apart from the label citing it as a type, which is printed, all labelling is in L. Bolus' handwriting. The second sheet contains five capsules of dissected leaves and flowers, all labelled in L. Bolus' handwriting. There is a printed label citing it as a type.

Section 3. Gibbaeum

Sect. Gibbaeum

Jacobsen, Handb. Succ. Pl. 3:1149 (1960); et in Sukk. Lex. :425 (1970)

Sect. Eugibbaeum

Wulff, Bot. Archiv 45:161 (1944)

Plants succulent, of various habit; leaves digitiform or hemispherical, connate at the base or for various lengths, up to almost to the apices. Indumentum various, always present, usually simple hairs, sometimes branched at the tip. Epidermal cells often all about the same size, sometimes of two different sizes.

Flowers white or magenta, rarely pink.

Three subsections, nine species.

Subsection 3.1 Gibbaeum

Subsect. Gibbaeum

Jacobsen, Handb. Succ. Pl. 3:1149 (1960); et in Sukk. Lex. :425 (1970)

Subsect. Gibbaeotypus

Wulff, Bot. Archiv 45:161 (1944)

Plants small succulent shrubs or carpets; leaves digitiform, silvery, yellowish or brownish. Indumentum of hairs branched at the tip or simple in one species. Epidermal cells all about the same size.

Flowers small for the genus; petaloid staminodes magenta.

Two species and one subspecies: G. pubescens subsp. pubescens, G. pubescens subsp. shandii and G.geminum.

5A. Gibbaeum pubescens (Lettsom ex Haw.) N.E. Br. subsp. pubescens

Gibbaeum pubescens (Lettsom ex Haw.) N.E. Br., Gard. Chron. 71:129 (1922); Tischer, Z. Sukkulentenk. 3 :227 (1927); L. Bol. S. Afr. Gard. Country Life 18:318 (1928); et in Notes Mesemb. allied Gen. 1:45 (1928); N.E. Br., Tisch. & Karsten, Mesembryanthema : 222 (1931); Jacobsen, Sukk. Pfl. :134 (1933); et in Succ. Pl. :181 (1935); Nel, Gibbaeum Handb. :84 - 86 (1953); Jacobsen, Handb. Succ. Pl. 3:1156 (1960); et in Sukk. Lex. :426 (1970)

Mesembryanthemum pubescens Lettsom ex Haw., Lettsom, Hort. Upton :34 (1781), nom. nud.; Haw., Obs. Gen. Mesemb. 2:138 (1795); Haw. Misc. Bot. :37 (1803); Haw., Syn. Pl. Succ. :250 (1819); Haw., Rev. Pl. Succ. :104 (1821); Ait. f., Hort. Kew. ed. 2 3:221 (1811); DC, Prodr. 3:424 (1828); Don, Syst. Gen. Gard. Bot. 3:131 (1834); Sond., Fl. Cap. 2:405 (1863); Berger, Mesembryanthemen und Portulacaceen :230 (1908); Marloth, Trans. S. Afr. Phil. Soc. 18:44 (1907). Type not found.

G. argenteum N.E. Br., Gard. Chron. 70:273 (1921) On stony ground a few miles from Ladismith, July 1919, fl., Pole Evans 6932 (K! holotype)

Plants forming cushions which become almost hemispherical with age, up to 45 cm in diameter; each stem with a pair of leaves at the tip and the remains

of old leaf-bases along its length. Leaves opposite, terete, one of a pair much larger than the other, larger leaf 18 - 27,3 - 40 mm long, 7,5 - 10,9 - 14 mm in diameter, the lesser 4 - 12,3 - 15 mm long and 4 - 9,6 - 13,6 mm in diameter; leaves silvery-grey, cream or glaucous, becoming pale glaucous green if over-watered in cultivation, densely pubescent. Indumentum of curved, simple hairlike projections from all epidermal cells except the guard and subsidiary cells of the stomata, the "hairs" with ± regular, sinusoid involutions on the walls. Epidermal cells uniform, hexagonal, 50 - 64 - 82 microns in diameter, walls somewhat bowed, sculpture absent; stomatal ratio 4 - 8%, stomatal aperture 14,5 - 16,5 microns long, cells 25 - 35,5 microns long, 6 - 10 microns wide, subsidiary cells 2 per stoma. Rootstock stout and woody.

Flowers solitary, 25 - 30 mm in diameter, peduncle ebracteate, 15 - 20 mm long, 5 - 10 mm in diameter; sepals 6, two large and fleshy, the others smaller with membranous margins, the larger sepals 12 mm long and 3 mm wide at the base, the lesser 10,5 mm long and 3 mm wide at the base; petals 30 - 40, 10 - 12 mm long, up to 1,0 mm wide, magenta (RHS rose bengal 25/1); stamens many, filaments 1,0 - 1,5 mm long; styles and stigmas 6, 1,0 - 1,5 mm long. Capsule 6-locular, 7 mm in diameter, 4,5 mm deep, hygrochastic, pale buff (RHS 407/3). Seeds brown, ca. 600 - 720 microns long, 350 - 500 microns wide, 250 - 300 microns

-DC, near Barrydale, October 1924, fl., Compton s.n. in NBG 1132/24 (BOL)

-DD, Lemoenshoek, July 1925, fr., Marloth 12154 (PRE); 10 miles from Barrydale, 11 January, 1948, fr., Kramer 266 (K); 7 miles from Warmwaterberg, 1 August 1948, nf., R. du Plessis 108 (BOL)

3321; -AD, nr. Ladismith, October 1906, fl., Pillans 888 (BOL)

locality data incomplete:
Ladismith division, October 1932, fl., Jordaan 15 (BOL); Little Karoo, September 1925, nf., Leipoldt 18607 (BOL, K); Little Karoo, 13 August 1943, nf., Compton s.n. in NBG 241/40 (BOL)

garden specimen: Kirstenbosch, October 1920, fl., Anon. s.n. (PRE)

spirit material: Ladismith district: 20 August 1946, fl., Anon. s.n. in STE-U 654 (STE-U)

The type species of the genus Gibbaeum is the commonest species in the group, G. pubescens subsp. pubescens. This plant forms small but conspicuous bushes with glaucous, pubescent, digitiform leaves. Nel's (1953 :86) statement that plants are visible at a range of more than 500 yards (450 m) was confirmed in the field - the plants at Lemoenshoek are easily seen at this distance, as glaucous patches on the background of the white quartz patches on which they live.

It seems that the present subspecies rarely if ever is found away from white quartz patches. On these patches, however, it is plentiful throughout the western Little Karoo. According to Joubert (pers. comm.), whereas in the 1920's one saw only a few plants on some patches, now (1974) the same quartz patches are almost completely overgrown with G. pubescens. In other words, this species, far from being rare or endangered, is on the increase.

The first use of the name Mesembryanthemum pubescens was by Lettsom in the Hortus Uptonensis (1781:34), where it is published as a nomen nudum. The name was taken up by Haworth (1795:137), who published the first description of the plant. This description is of a plant with digitiform leaves "covered with ... hoary pubescence". The only species of Gibbaeum with such leaves is the one now known as G. pubescens subsp. pubescens. No specimens or paintings from this period have survived, and it is doubtful whether any were made. It is therefore necessary to choose a neotype.

It is proposed that L. Bolus s.n. in NBG 698/32, from Warmbaths near Barrydale, be designated as a neotype. This specimen consists of seven fragments, one with flower and two with fruit. On the same sheet is L. Bolus s.n. in NBG 699/32, from the same locality, consisting of five fragments, one each with flower and fruit.

13 Lampranthus godmaniae (L. Bol.) L. Bol., Notes Mesembryanthemum 3 : 169 (1939); Jacobsen, Handb. Sukk. Pfl. 3 : 1434 (1955); idem, Handb. Succ. Pl. 3 : 1200 (1960); idem, Sukk. Lex. : 441 (1970); idem, Lex. Succ. Pl. : 495 (1974)

Syntypes: near Springbok, August - September 1929, L. Bolus s.n. in BOL 18992 (BOL!)
near Springbok, September - October 1929, Dame Alice Godman s.n. in NBG 1806/29 (BOL!)

Mesembryanthemum godmaniae L. Bol., Notes Mesembryanthemum 2 : 141 (1929)

Syntypes: as above

M. godmaniae var. grandiflorum L. Bol., Notes Mesembryanthemum 2 : 326 (1932)

Holotype: between Patats River & Karoopoort, September 1931, Compton 3719 (BOL!)

L. godmaniae var. grandiflorus (L. Bol.) L. Bol ex Jacobsen, Handb. Sukk. Pfl. 3 : 1435 (1955), comb. illegit.; Jacobsen, Handb. Succ. Pl. 3 : 1200 (1960); idem, Sukk. Lex. : 442 (1970); idem, Lex. Succ. Pl. : 495 (1974)

Holotype: as above

Succulent shrubs, ca. 45 cm. high and 30 cm. in diameter. Internodes smooth, buff, ca. 27 mm long and 2,5 mm in diameter in the first two years of growth. Leaves sharply to obscurely triquetrous, grey, 11 - 24,5 - 53 mm long, 2 - 3,5 - 6 mm wide and 2 - 3,5 - 6 mm deep; hardly sheathing the stem. Flowers in threes, pedicels ca. 40 mm long and 1 mm in diameter; flowers magenta to purple, ca. 49 mm in diameter. Bracts up to 22,5 mm long and 2,5 mm wide, sepals 5, ca. 11 mm long and up to 5 mm wide, the inner 3 somewhat smaller, with membranous margins; petals (petaloid staminodes) ca. 60 - 70 in 3 series, 8 - 18 - 29,5 mm long, up to 2 mm wide; non-petaloid staminodes ca. 40 - 65, white, ca. 4,5 - 7,5 mm long, grading into the petaloid staminodes. Stamens many, filaments pink, ca. 3 - 6 mm long, anthers yellow; stigmas 5, 1,5 - 2 - 3 mm long, subulate. Capsule 5 - locular ca. 9 mm in diameter and 8 mm deep, woody, pale grey to ochre, valves inconspicuously ridges, valve-wings ca. 4 mm long and up to 2 mm wide, separate from the valve for about half of their length; placental tubercle absent; covering membranes present, covering most of the

p #85 missing!

sculpture on the outer wall of fine dots, walls straight, stomatal ratio 9,5%, stomatal aperture 26 microns long, guard cells 51 microns long and 10 microns wide, subsidiary cells 2 per stoma. Rootstock composed of a conspicuous taproot and numerous lateral roots.

Flowers solitary, 35 - 40 mm in diameter; peduncle 13 mm long, 3 - 5 mm in diameter; sepals 6, two large and fleshy, the others smaller with membranous margins, the larger sepals 9,5 mm long and up to 4 mm wide, the lesser ones up to 6 mm long and 4 mm wide; petals 52 - 66, magenta (RHS rose bengal 25/1), 14 - 19 mm long, up to 1,5 mm wide, narrowly spatulate; staminodes 20 - 125, 4 - 6 mm long; stamens 95 - 125, filaments 2 - 4,4 - 5,5 mm long; styles and stigmas 6, 1 - 3 mm long. Capsule 6-locular, 6,5 mm in diameter, 4 mm deep, obconical, hygrochastic, pale buff (RHS 407/3). Seeds 600 - 720 microns long, 350 - 500 microns wide and 300 - 450 microns deep, ovoid with a funicle 220 - 350 microns long; surface pattern of hemispherical humps, some collapsed to discoid humps with central depressions, close packed; funicle pattern of discoid to rectangular close packed humps; the surface with small amounts of wax.

Chromosome number 2n = 36 (Wulff, 1944; de Vos, 1951)

Specimens seen

CAPE: 3320; -AC, 4 miles South of Touws River, 28 June 1948, nf., Acocks 14551 (BOL)

deep, ovoid with a funicle 130 - 250 microns long; surface pattern of cylindrical to elongate humps ca. 10 microns high, up to 15 microns long, separated by up to 1½ times their own length; pattern elements on the funicle roughly rectangular to discoid, close packed. Chromosome number 2n = 18 (Wulff, 1944, de Vos, 1951).

Specimens seen

CAPE: 3320; -BD, between Ladismith and Laingsburg, December 1904, fr., Pillans s.n. (K); between Ladismith and Laingsburg, 1906, fl., Pillans 888A (BOL); 20 miles from Ladismith, 26 September 1932, fr., Lewis s.n. in NBG 2464/32 (BOL)

-CB, Grootvlakte farm, Montagu div., 3 September 1970, fr., Kotze 23 (STE)

-CC, Bonnievale, 3 September 1935, fl., Van der Merwe 128 (BOL)

-CD, Warmbaths near Barrydale, May - June 1932, fl., L. Bolus s.n. in NBG 698/32; Warmbaths near Barrydale, May 1932, fl., L. Bolus s.n. in NBG 699/32 (BOL)

-DA, 5 miles south-west of Kareevlakte, 29 June 1948, nf., Acocks 14575 (BOL); between Montagu and Ladismith, May 1933, fr., Salter 3136 (BOL); Kareevlakte, August 1933, fl., Joubert 184 (BOL)

-DB, Hondewater, 14 August 1925, fl. Muir 3662 (K); 6 miles west of Kareevlakte, 18 March 1973, fr., Glen 581 (BOL)

-DA, Never-never rd., Ladismith, January 1944, fl., Minnaar s.n. (BOL); north road between Montagu and Ladismith, May 1933, fr., Salter 3137A, Kareevlakte, 18 June 1974, fl., Glen 807 (BOL)

-DB, 44 miles north-east of Montagu, 5 July 1971, fl., Wisura 2080 (NBG); near Touwsberg, July 1925, fl., Archer s.n. (K); near Touwsberg, 24 May 1919, Pole Evans 6921 (K, holotype); Hondewater, 18 June 1974, Glen 808 (BOL)

garden material: Hort. N.E. Brown, June 1922, fl., Pole Evans s.n. (K); hort. N.E. Brown, May 1923, fl., N.E. Brown s.n. (K); Hort. L. Bolus, 25 October 1941, fl., Van der Merwe s.n. in BOL 22110 (BOL)

The variety differs from the type in having green, yellowish or reddish leaves with pubescence that appears stellate under a hand-lens. In the field the leaves of a healthy specimen appear deep green by transmitted light (viewed against the sun) and apple green by reflected light (sun behind the observer). In the field, plants may be confused with G. gibbosum, as the size, shape and colouration of the leaves in that species are almost identical to G. pubescens subsp. shandii. However, the former is glabrous while the latter is pubescent. One specimen observed flowering near Hondewater had petaloid staminodes that were much more intensely pink along the edges than along the centre.

G. pubescens subsp. shandii is not restricted to white quartz patches as is G. pubescens subsp.

pubescens; large populations were seen near Hondewater on shale and is plentiful where it occurs. This subspecies is not as widespread as subsp pubescens, being restricted to the Kareevlakte and near Hondewater. In the present author's experience, Nel's (1953:32 - 33) assertion that both subspecies may be found together, is incorrect. On the north road between Montagu and Ladismith, colonies are found close together, but each colony is either one or the other, not both subspecies.

The type specimen consists of three fragments, without flower or fruit. Two of these fragments are evidently material that was sent to Brown from South Africa, while the third was raised from seed in London. Both labels are in Brown's handwriting.

6. Gibbaeum geminum N.E. Br., Gard. Chron. 71:129 (1922); N.E. Br., Gard. Chron. 79:215 (1926); N.E. Br., Gard. Chron. 81:430 (1927); Tisch., Z. Sukkulentenk. 3:227 (1927); L. Bol., Notes Mesemb. allied Gen. 1:57 (1928); L. Bol., S. Afr. Gard. Country Life 18:126 (1928); N.E. Br., Tisch., Karsten, Mesembryanthema :216 (1931); Jacobsen, Sukk. Pfl. :133 (1933); Jacobsen, Succ. Pl. :179 (1935); Nel, Gibbaeum Handb. : 90 - 93 (1953); Jacobsen, Handb. Succ. Pl. 3:1152 (1960); Jacobsen, Sukk. Lex. :426 (1970)

Holotype: Little Karoo, south-west of Touwsberg, Ladismith Div., June 1919, nf., Pole Evans 6925 (K!)

Plants with trailing stems, forming mats up to 60 cm in diameter; stems rooting at the nodes; leaves opposite, terete, brownish, densely pubescent, one of a pair much larger than the other, larger leaf 14 - 18,5 - 28 mm long, 4 - 9 mm in diameter, the lesser 3 - 9 mm long, 3 - 8 mm in diameter. Indumentum composed of much-branched, unicellular trichomes, the branches being short to half as long as the main trichome, with slightly undulate walls; the trichomes being on all epidermal cells except the guard and subsidiary cells of the stomata; epidermal cells uniform, hexagonal, with straight walls, 37 - 64 microns in diameter, outer cell walls with pronounced sculpturing, mostly lines; stomatal ratio 2,7%, stomatal aperture 17,5 microns long, guard cells 31 microns long and 11 microns wide, subsidiary cells 2 per stoma. Roots mostly fibrous, fusiform.

Flowers solitary, 13 mm in diameter; peduncle ebracteate; sepals 6, two slightly larger and fleshier than the rest, the two larger 5,2 mm long and up to 1,7 mm wide, the rest 4,7 mm long and up to 1,7 mm wide; petals 25 - 30, magenta to pale magenta, 6 - 9 - 10,5 mm long, up to 1,2 mm wide, narrowly spatulate; staminodes absent; stamens 30 - 35, filaments 2 - 4,2 mm long; styles and stigmas 6, reniform, 1 - 2 mm long. Capsule 6-locular, 4 mm in diameter, 2 mm deep, obconical, hygrochastic, pale buff. Seeds pale reddish-brown, 600 - 700 microns long, 340 - 530 microns wide

Plants with trailing stems, forming mats up to 60 cm in diameter; stems rooting at the nodes; leaves opposite, terete, brownish, densely pubescent, one of a pair much larger than the other, larger leaf 14 - 18,5 - 28 mm long, 4 - 9 mm in diameter, the lesser 3 - 9 mm long, 3 - 8 mm in diameter. Indumentum composed of much-branched, unicellular trichomes, the branches being short to half as long as the main trichome, with slightly undulate walls; the trichomes being on all epidermal cells except the guard and subsidiary cells of the stomata; epidermal cells uniform, hexagonal, with straight walls, 37 - 64 microns in diameter, outer cell walls with pronounced sculpturing, mostly lines; stomatal ratio 2,7%, stomatal aperture 17,5 microns long, guard cells 31 microns long and 11 microns wide, subsidiary cells 2 per stoma. Roots mostly fibrous, fusiform.

Flowers solitary, 13 mm in diameter; peduncle ebracteate; sepals 6, two slightly larger and fleshier than the rest, the two larger 5,2 mm long and up to 1,7 mm wide, the rest 4,7 mm long and up to 1,7 mm wide; petals 25 - 30, magenta to pale magenta, 6 - 9 - 10,5 mm long, up to 1,2 mm wide, narrowly spatulate; staminodes absent; stamens 30 - 35, filaments 2 - 4,2 mm long; styles and stigmas 6, reniform, 1 - 2 mm long. Capsule 6-locular, 4 mm in diameter, 2 mm deep, obconical, hygrochastic, pale buff. Seeds pale reddish-brown, 600 - 700 microns long, 340 - 530 microns wide

and 300 - 450 microns deep, ovoid with a funicle 130 - 280 microns long; surface pattern of hemispherical to elongate elements, rarely discoid by collapse, or absent, elements 15 - 20 microns high, 25 microns in diameter to 60 microns long and 25 wide, separated by up to 15 microns; funicle pattern elements rectangular with irregular margins, tessellated; surface with minute amounts of wax. Pollen grains separate or rarely in clumps of two or three grains, ellipsoidal, polar axis ca. 16 - 20 microns long, equatorial axis 11 - 16 microns long, or spherical, ca. 16 microns in diameter, tricolpate, colpi extending almost the full length of the grain, ca. 0,5 - 0,8 microns wide, ektexine pitted and with projections, these hemispherical to conical. Chromosome number 2n = 36 or 54 (Wulff, 1944; de Vos, 1951)

Specimens seen

CAPE: 3320; -DA, southwest of Touwsberg, January 1919, nf., Pole Evans 6925 (K!, holotype)

-DB, between Warmwaterberg and Bellair Dam, 7 October 1973, fl., Glen 701 (BOL)

-DC, near Barrydale, May 1932, fr., L. Bolus s.n. in NBG 703/32

-DD, Hondewater, August 1925, fl., Muir 3664 (K, PRE); between Barrydale and Ladismith, September 1929, fl., Van der Merwe 117 (BOL)

3321; Riversdale, June 1931, nf., Primos s.n. (BOL); Prince Albert Division, January 1925, nf., Leipoldt s.n. (BOL)

Garden specimens: hort. Bonnievale, 3 September 1935, nf., Van der Merwe 129 (BOL); Kirstenbosch, no date, fl., fr., Muir s.n. (BOL)

This species has horizontal stems, so that the plants form small mats which are highly distinctive in the field. The leaves are brown to olive green, rendering them very visible against the white quartz on which they grow. The digitiform leaves are much smaller than those of G. pubescens subsp. pubescens. The flowers are deep magenta and are borne in October. In the herbarium, this species may be recognised by its small, digitiform leaves and the much-branched trichomes. The specific name is derived from the Latin word for a twin, and this appears to refer to the fact that N.E. Brown considered the pubescence of this species to be exactly the same as that of G. pubescens subsp. shandii.

The type sheet of this species is divided into three. On the lowest part are three fragments of a plant received from South Africa and cultivated in London for nine years. The middle section contains a capsule with two small, nonflowering fragments, and a large mounted fragment. The uppermost section is devoted to two small plants raised from seed in London. There are no readily visible flowers or fruits. The capsule is labelled with the collection number and the word "Type !" in Brown's handwriting. The lower two sections

are labelled with the same number in Brown's handwriting, and the label of the top section contains the words "raised from the Type !", again in Brown's handwriting.

Subsection 3.2 Muiriopsis Wulff

Muiriopsis Wulff, Bot. Archiv 45:159 (1944); Jacobsen, Handb. Succ. Pl. 3: 1149 (1960); et in Sukk. Lex. :425 (1970)

Plants small, clump-forming succulents, the apices of the leaves at ground level in nature; leaves connate almost to the apices, the fissure not extending across more than half the width of the apex of the body. Indumentum present or absent, when present, of simple, slightly curved hairs. Epidermal cells of two different sizes.

Flowers pink.

Two species, G. pilosulum and G. nuciforme

7. Gibbaeum pilosulum (N.E. Br.) N.E. Br., Gard. Chron. 78:484 (1925); et in Gard. Chron. 79: 234 (1926); Tischer, Z. Sukkulentenk. 3:227 (1927); N.E. Br., Tisch., Karsten, Mesembryanthema :220 (1931); Jacobsen, Sukk. Pfl. :133 (1933); Jacobsen, Succ. Pl. :181 (1935); Nel, Gibbaeum Handb. :58 - 59 (1953); Jacobsen, Handb. Succ. Pl. 3:1156 (1960); Boom, Succulenta 1963(1):71 (1963); Jacobsen, Succ. Lex. :426 (1970)

Mesembryanthemum pilosulum N.E. Br., Jl. Linn. Soc. Bot. 45: 98 (1920)

Conophytum pilosulum (N.E. Br.) N.E. Br., Gard. Chron. 71: 214 (1922)

G. molle N.E. Br., Gard. Chron, 79: 216 (1926); Tisch., Z. Sukkulentenk. 3: 227 (1927)
Adamskraal, April 1926, Muir 3210 (K!, BOL!); between Touwsfontein and Allemorgensfontein, Muir 3796 (K); Ladismith Karoo, 25 March 1924, Marloth 11879 (K), syntypes.

G. helmiae L. Bol., Notes Mesemb. allied Gen. 2: 402 (1933); Zebra, Helm s.n. in NBG 1717/32 (BOL!, holotype)

Holotype: South of Touwsberg, 7 Nov. 1924, fl., Pole Evans 6927 (K!)

Plants forming clumps ca. 4 - 20 cm in diameter, tips of the leaves level with the ground; each stem with one pair of leaves at the tip and sometimes with the adhering remains of old leaves. Leaves opposite, each pair connate to form a small clavate body, 13 - 38 mm long and 12,5 - 25 mm in diameter, with a fissure about one third as long as the diameter, sometimes off-centre, very pale green in nature, deeper green in cultivation. Indumentum of straight hairs of varying length, on all cells except the guard cells and subsidiary cells of the stomata when all cells are of similar size, or only

on the larger cells when the cells are of two size ranges. Epidermal cells all of similar sizes or of two different size ranges; if the former, then 53 - 75 microns in diameter, four- to six-sided in optical section, with straight to curved radial walls, outer wall sculptured with dots; if the latter, then the larger cells roughly circular in optical section, 69 - 99 microns in diameter, and the smaller cells irregular in outline so as to fit between the larger cells, radial walls straight or curved, 27 - 71 microns in diameter, outer walls of cells of both kinds sculptured with dots and lines; stomatal ratio 5 - 9,5%, stomatal aperture 12 - 1 microns long, guard cells 21 - 27 microns long and 5 - 6 microns wide. Subsidiary cells 2 per stoma. Rootstock fusiform to woody.

Flowers solitary, 17 - 27 mm in diameter; peduncle ebracteate, 11 - 13 - 14 mm long, 2,5 - 3 mm in diameter; sepals 6, all alike, oblong with acute tips and membranous margins, 4 - 6 mm long, 1 - 2 mm wide; petals 30 - 40, biseriate, pink to lilac, 6 - 16 mm long, up to 2 mm wide; nonpetaloid staminodes absent or up to 15, up to 6 mm long, stamens 30 - 40, filaments 2 - 4,8 - 6 mm long; styles and stigmas 6, rarely 5, filiform, 5 - 7 mm long. Capsule 6-locular, rarely 5-locular, 5,5 - 6,5 mm in diameter, 4 - 5 mm deep, charcoal grey or pale buff. Seeds pale to medium red-brown, 433 - 633 microns long, 310 - 460 microns wide and 360 - 530 microns deep, with a 145 - 300 micron long funicle; pattern on the seed surface

of circular humps to elongate ridges, pattern elements 17 - 26 microns in diameter, sometimes with an irregular pattern of ridges and furrows, 2 - 4 microns apart; pattern on the funicle of triangular, rectangular or irregular elements, 11 - 20 microns in diameter, ca. 0,5 micron apart. Wax present in small quantities on the seed surface. Chromosome number 2n = 18 (Wulff, 1944; de Vos, 1951).

Specimens seen

CAPE: 3320; -AD, 9 miles southeast of Touws River, March 1952, fr., Villet s.n. (BOL)

-BD, 20 miles from Ladismith towards Laingsburg, 26 September 1932, fr., Lewis s.n. in NBG 2731/32 (BOL); between Montagu and Ladismith, April - May 1933, fr., Salter 3140 (BOL)

-CB, top of Ouberg Pass, no date, fr., Lewis s.n. in NBG 2002/33 (BOL)

-CC, Adamskraal, April 1926, fr., Muir 3210 (BOL, K, syntype of G. molle)

-DB, South of Touwsberg, 7 November 1924, fl., Pole Evans 6927 (K, holotype); between Warmwaterberg and Bellair Dam, 7 October 1973, fr., Glen 700 (BOL)

-DD, Barrydale district, 20th July 1959, fr., De Kock GN12790 (PRE); Klein Doorn River, May 1932, nf., L. Bolus s.n. in NBG 738/32 (BOL); 7 miles from Warmwaterberg, 1 Aug. 1955, R. du Plessis 107 (BOL)

3321; -CA, Calitzdorp 8 June 1935, nf., Blackburn s.n. (BOL)

3322; -CB, Zebra, 28 July 1933, fl., Helm s.n. in NBG 1717/32 (BOL, holotype of G. helmiae); Zebra, 21 July 1938, fl., R. du Plessis s.n. in NBG 936/37 (BOL)

without locality: 1 November 1932, fr., Joubert 50 (BOL); Laingsburg district 1932, fr., Joubert 3 (BOL); Ladismith Karoo, 25 March 1924, fr., Marloth 11879 (K, syntype of G. molle)

spirit material: 3321 CA; between Ladismith and Barrydale, November 1938, fr., Van der Spuy s.n. (BOL)

This species differs from G. nuciforme in having a conspicuous covering of long hair. Like that species, it has emerald green leaves the apices of which are level with the ground. It grows in white quartz patches, in which it is very well camouflaged.

The type specimen consists of three mounted fragments and a capsule. None of the mounted fragments has either flower or fruit. One of these fragments is much larger than the other two, having been cultivated at Kew for four years. In the capsule is a loose fragment consisting of a pair of leaves and a flower. There are two labels, both in N.E. Brown's handwriting, one citing the specimen as the type.

8. Gibbaeum nuciforme (Haw.) Glen, comb. nov.

Mesembryanthemum nuciforme Haw., Obs. Gen. Mesembryanthemum 2:129, 440, 450 (1795) - basionym; Haw., Misc. Bot. :22 (1803); Haw., Syn. Pl. Succ. :204 (1812); Ait. f., Hort. Kew. ed. 2, 3:213 (1811); DC., Prodr. 3:418 (1828); Don, Syst. Gen. Gard. Bot. 3:127 (1834); Berger, Mesembryanthemen und Portulacaceen :283 (1908)

M. cryptopodium Kensit, Trans. Roy. Soc. S. Afr. 1:150 (1910). Holotype: between Wittepoort and Laingsburg, Pillans 892 (BOL!)

Conophytum nuciforme (Haw.) N.E. Br., Gard. Chron. 72:84 (1922)

Derenbergia cryptopodia (Kensit) Schwantes, Z. Sukkulentenk. 2:138 (1925)

D. nuciformis (Haw.) Schwantes, Z. Sukkulentenk. 2:138 (1925)

G. cryptopodium (Kensit) L. Bol., Notes Mesemb. allied Gen. 2:402 (1933); Nel, Gibbaeum Handb. :60 (1953); Jacobsen, Handb. Succ. Pl. 3:1153 (1960); Jacobsen, Sukk. Lex. :426 (1970)

Plant a dwarf succulent, the top surface of which is level with the ground and usually almost the same colour; clumps up to 10 cm in diameter; each stem with one pair of leaves at the tip, sometimes with old leaf-bases adhering, these paper-thin, buff. Leaves opposite, connate for the whole of their length, forming globular to clavate bodies, with a fissure about a third of the width of the plant across the top, central or somewhat displaced to one side; bodies 12 - 30 mm long

and 5 - 20 mm in diameter, reddish, green or glaucous. Indumentum none; epidermal cells of two distinct sizes, the larger cells round, elliptical or angular with many straight to convex sides, 71 - 80 - 96 microns in diameter, outer wall with sculpturing of fine dots and sometimes irregular lines; the lesser irregularly pentagonal, with at least one concave side, so as to fit between the larger cells, thus with two or three sides much shorter than the others, the short axis 35 - 50 microns long, the long one 65 - 72 microns long, the outer wall sparsely to densely sculptured with dots; stomatal ratio 2,5 - 13%, stomatal aperture 12 - 13 microns long, guard cells 23,5 - 27 microns long and 6 - 7,5 microns wide, subsidiary cells 2 per stoma. Rootstock stout and woody.

Flowers terminal, solitary, 27 mm in diameter; peduncle ebracteate, 20 mm long, 5 mm in diameter; sepals 6, two somewhat larger than the others, these 5 mm long and up to 1 mm wide, the others 4,5 mm long and up to 1 mm wide; petals 30 - 40, biseriate, up to 12 mm long and 2 mm wide, pink; filaments 5 mm long; styles and stigmas 6, filiform, 7 mm long. Capsule 6-locular, 6 mm in diameter and 4 mm deep; seeds 430 - 585 microns long, 320 - 440 microns wide and 340 - 470 microns deep, with a 120 - 180 micron-long funicle; pattern on the surface of hemispherical, conical or elongate humps, randomly arranged, rarely absent in patches; pattern on the funicle of rectangular to irregular humps in rows, close packed.

Chromosome number 2n = 18 (de Vos, 1951)

Specimens seen:

CAPE: 3320; -BB, between Wittepoort and Laingsburg, no date, fl., Pillans 892 (BOL, holotype of G. cryptopodium)

-BD, Rooinek Pass, 31 May 1973, fl., Glen 672 (BOL, lectotype); Rooinek Pass, 31 May 1973, fr., Glen 673 (BOL); Rooinek Pass, 31 May 1973, fr., Glen 689 (BOL)

-DD, Barrydale district, 15 July 1959, fr., De Kock GN 12790A, (PRE); near Warmwaterberg, 7 October 1973, fr., Glen 706 (BOL)

without locality: October 1916, fl., Pillans s.n. (K)

spirit material: 3320; -DD, between Ladismith and Barrydale, November 1938, fr., Van der Spuy s.n. (BOL)

This species is one of the most difficult of Gibbaeinae to see in the field, and it is likely that the paucity of specimens can be attributed to this rather than to any actual rarity. Plants do not grow above the surface of the soil, and have emerald green or reddish glabrous leaves which blend in well with their surroundings.

This species shows no specificity about soil type; it occurs on both shale (in the Rooinek Pass) and on quartz (at Lemoenshoek). At the latter locality it grows socially with G. pubescens subsp. pubescens and G. heathii. The only apparent (but effective) barrier to hybridisation is flowering time; G. nuciforme flowers in July, while the other species flower in October and September respectively.

Sonder (1863) regarded M. nuciforme Haw. as a synonym of M. minutum Haw. (now Conophytum minutum (Haw.) N.E. Br.). Berger (1908) dismisses this with the words ".... mit der sie indessen nichts zu tun haben kann." The entry in Flora Capensis combines a description of the Conophytum with the locality of the Gibbaeum. The differences between Conophytum and G. nuciforme are that the former has 5-locular capsules, the latter 6-locular, and the petaloid staminodes in the former are united for about half their length into a tube.

The author has in his possession a photograph of a note in N.E. Brown's handwriting, in which the combination made above, is proposed. It appears that this note, the original of which is in the archives at Kew, was never published.

The descriptions of the vegetative parts - it appears that Haworth saw neither flowers nor fruit - in the original descriptions of M. nuciforme and M. cryptopodium are virtually identical, even to the words used.

Nel (1953) regarded the names G. molle and G. helmiae as synonyms of this species. However, the type material of both exhibits the same kind of hair as possessed by G. pilosulum, so both must be transferred to that species.

A neotype is proposed because no material or picture of M. nuciforme that was available to Haworth has survived. Glen 672, from Rooinek Pass, is proposed as the neotype because the only other specimen at BOL, namely the type of M. cryptopodium Kensit, is extremely meagre.

Subsection 3.3 Imitariopsis Wulff emend. Glen

Imitariopsis Wulff, Bot. Archiv 45:165 (1944); Jacobsen, Handb. Succ. Pl. 3:1149 (1960); et in Sukk. Lex. :425 (1970)

Plants small clump-forming succulents; leaves shortly triquetrous or keeled-hemispherical, keels obscure in one species, glaucous, greenish or brownish. Indumentum of more or less straight, simple or branched hairs, sometimes tessellate or with projections from the walls. Epidermal cells all about the same size.

Flowers white to magenta.

Four species; G. dispar, G. album, G. nebrownii, and G. austricolum

The alterations in the circumscription of this subsection are such as to exclude G. angulipes (transferred to sect. Macrogibbaeum) and to include G. nebrownii (formerly Imitaria) and G. austricolum (new species). The subsection is now composed of all those species with hemispherical, keeled, hairy leaves.

9. Gibbaeum dispar N.E. Br., Gard. Chron. 79:215 (1926); N.E. Br., Gard. Chron. 81:430 (1927); Tisch., Z. Sukkulentenk. 3:227 (1927); Tisch., Monatsschr. D. Kakt. Ges. 3:17 (1932); Jacobsen, Sukk. Pfl. :132 (1933); Jacobsen, Succ. Pl. :179 (1935); Nel, Gibbaeum Handb.

:68 - 71 (1953); Jacobsen, Handb. Succ. Pl. 3:1152 (1960); Boom, Succulenta 1963(1) :70 (1963); Jacobsen, Sukk. Lex. :426 (1970)

Holotype: Road between Waterval and Van Wijk's Dorp, Ladismith Division, Dec. 1925, Muir 3796 (K!)

Dwarf succulents to about 10 cm in diameter, growing in pale grey-brown shale, in cracks in the rock; each stem with one or two pairs of leaves, each growth with one to about six pairs of leaves. Leaves opposite, hemispherical to hemi-obovoid, brownish, closely matching the surrounding shale, one of a pair somewhat larger than the other, the larger leaf 12 - 34 mm long and 9 - 23 mm in diameter, the lesser 10 - 29 mm long and 9 - 23 mm in diameter. Indumentum of trichomes projecting from every epidermal cell except the guard cells and subsidiary cells of stomata, the trichomes almost straight, with many short projections along their lengths, and often (about half) shortly dichotomously branched near the tip. Epidermal cells uniform, hexagonal, 80 - 97 microns in diameter, walls straight to slightly bowed, outer wall sculptured with dots and fine lines; stomatal ratio 8,1%, stomatal aperture 20 microns long, guard cells 38 microns long and 11,5 microns wide, subsidiary cells 2 per stoma. Roots mostly fusiform.

Flowers solitary, up to 27 mm in diameter; peduncle 17,5 mm long and 7,5 mm in diameter; sepals 6, uniform, up to 4 mm long and 2,4 mm wide; petals

25 - 50, biseriate, 12 - 20 mm long, up to 1,7 mm wide, pink; non-petaloid staminodes absent; stamens 30 - 60, filaments 3 - 10 mm long; styles and stigmas 6, subulate, 3 - 5,3 - 6 mm long. Capsule 4,5 mm in diameter and 3 mm deep; seeds maroon-brown, 600 - 650 microns long, 400 - 440 microns wide and 340 - 370 microns deep, funicle 175 - 380 microns long; pattern on both central and funicle surface of hemispherical, elongate or irregular humps, 20 - 35 microns in diameter on the central surface, 11 - 29 microns in diameter on the funicle surface, spaced ca. 0,5 microns apart. Chromosome number 2n = 18 (Wulff, 1944; de Vos, 1951)

Specimens seen

CAPE: 3321; -CB, 2 miles from Vanwyksdorp, no date, fr., Joubert 42 (BOL) Vanwyksdorp, 7 July 1950, fl., H. Hall s.n. in NBG 1329/49 (BOL)

-CD, 5 miles south of Vanwyksdorp, 5 July 1971, fl., Wisura 2090 (NBG); between Waterval and Vanwyksdorp, December 1925, fr., Muir 3797 (K); 10 km south of Vanwyksdorp, 26 May 1973, fl., Glen 668 (BOL)

Locality data incomplete: Riversdale Div., August 1928, fl., Muir s.n. (K)

There are two capsules and a mounted plant on the type sheet. Each capsule contains an unmounted plant, and one of these has a fruit. The label, in N.E. Brown's handwriting, bears the words "Type specimen !".

In the field, this plant may be distinguished by the fact that it usually grows on shale, although one locality is known (Joubert, pers. comm.), where it grows on mixed shale and quartz. The leaves are hemispherical, hairy, and usually the same shade of brown as the shale.

In the herbarium, the most distinctive feature is the indumentum, which consists of simple and branched hairs in about equal numbers.

This species is rather rare, and is restricted to a small area of the Little Karoo near Vanwyksdorp. The specific name is derived from a Latin word meaning "unlike". This species lives in an area apart from the other species of the genus, and does not resemble any other species very closely.

10. Gibbaeum austricolum Glen, sp. nov.

G. haagei Schwantes, Beitr. Sukkulentenkunde und -pflege 1938 :89 - 91 (1938), nom. rej.; Nel, Gibbaeum Handb. :109 (1953); Jacobsen, Handb. Succ. Pl. 3:1153 (1960); Jacobsen Sukk. Lex. :426 (1970); non G. haagei Schwantes ex Jacobsen, Succ. Pl. :179 (1935), nom. illegit.

G. haagei Schwant. var. parviflorum L. Bol., Jl. S. Afr. Bot. 32:128 (1966); Jacobsen, Sukk. Lex. :426 (1970)

Holotype: Oudekraalskop, 21 October 1973, fl., Glen 714 (BOL!); plants viva Horto Botanico Stellenbossiensi est.

A Gibbaeo albo foliis longioribus, trichomatibus fere rectis florisque roseis vel amethysteis, haud albis, differt; a G. velutino foliis parvioribus, saepe glaucis, trichomatibus non ramosis, differt.

Planta succulenta, parva, inconspicua, caespedes ad 9 cm diametro; folia ad ca.10, opposita, hemisphaerica, rarius digitiformia, rarissime subtriquetra, vel ellipsoidea vel ovoidea, maiora minora subaequitans vel valde maiora; 14 - 59 mm longa; 6 - 27 mm diametro; minora 11 - 42 mm longa, 5 - 13 - 30 mm diametro; valde obtuse carinata si hemisphaerica, rare hamatum vel mentatum si digitiformia-triquetra. Indumentum confertum, trichomata unicellularia, non ramosa, rectiuscula, rarius bis vel ter ramosa, rarissime folia glabrescentia.

Flores terminales, unici, amethystei vel rosei, ad 25 mm diametro; sepala 6, 8,5 mm longa, 3,8 mm lata; staminodia petaloidea 40 - 75, biseriata, 10 - 19 mm longa, usque ad 1,9 mm lata; staminodia nonpetaloidea 0 - 50, 2,5 - 8,5 mm longa; stamina 70 - 160, fila 2 - 6 mm longa, antheri pollenque flavi; styli stigmataque 6; subulati, 0,8 - 4 mm longi. Capsula 6-locularis, loculis tectatis, 6 - 7 mm diametro, ca. 4 mm profunda; semini subferruginei vel subcinnamomei, 600 - 835 microns longi, 375 - 520 microns lati et 300 - 420 microns profundi, funiculo 180 - 250 microns longo; ornamentum superficiei e membris enormibus tessellatis, enorme disposita, compositum, vel partim nullum; ornamentum funiculi e membris rectangularibus vel enormibus, tessellatis, ordinis enormibus disposita.

Small succulents, clumps to 9 cm in diameter; leaves to ca. 10, opposite, hemispherical, ovoid or ellipsoid, more rarely digitiform or very rarely subtriquetrous, the larger about the same size as the smaller of a pair or much larger; the larger 14 - 59 mm long and 6 - 27 mm in diameter, the lesser 11 - 42 mm long and 5 - 13 - 30 mm in diameter; distinctly obtusely keeled if hemispherical, rarely with a "chin" or hooked apex if not; indumentum dense, of unicellular, unbranched, almost straight hairs, more rarely hairs twice or three times branched, very rarely leaves glabrescent.

Flowers terminal, solitary, magenta or pink, to 25 mm in diameter; sepals 6, 8,5 mm long, 3,8 mm wide; petaloid staminodes 40 - 75, biseriate, 10 - 19 mm long, up to 1,9 mm wide; nonpetaloid staminodes 0 - 50, 2,5 - 8,5 mm long; stamens 70 - 160, filaments 2 - 6 mm long, anthers and pollen yellow; styles and stigmas 6, subulate, 0,8 - 4 mm long. Capsule 6-locular, locules with covering membranes, 6 - 7 mm indiameter, ca. 4 mm deep; seeds pale red-brown, 600 - 835 microns long, 375 - 520 microns wide and 300 - 420 microns deep, with a 180 - 250 micron-long funicle; pattern on the surface mostly of irregular tessellate elements irregularly arranged, or absent in patches; pattern on the funicle of rectangular to irregular elements in irregular rows.

Specimens seen

CAPE: 3420; -AA, Witkop, 31 August 1962, fl., Van Breda s.n. in NBG 1754/62 (BOL); Uitvlugt, 15 June 1974, fr., Glen 804 (BOL)

-AB, 15 km south of Swellendam, 28 May 1973, fr., Glen 666 (BOL); Swellendam, 14 November 1956, fr., Anon. s.n. in NBG 719/51 (BOL)

-BA, Oudekraalskop, 28 May 1973, fr., Glen 659 (BOL); Oudekraalskop, 21 October 1973, fl., Glen 714 (BOL, holotype)

-BC, near Malgas and Infanta, April 1943, fl., W. Otzen s.n. (BOL); 1 km. west of Malgas, 28 May 1973, fr., Glen 665 (BOL)

The name G. haagei was first used in 1935 (Schwantes in Jacobsen, 1935) for the tetraploid strain of G. petrense. The description was published in English only, after 1 January 1935, thus contravening Art. 36 of the International Code of Botanical Nomenclature (Stafleu et al., 1972). A different plant was named G. haagei, again by Schwantes (1938). This plant was provided with a Latin description, so that the name was validly published. However, as it is a later homonym of the earlier, illegitimate name, it must be rejected in terms of Art. 64 of the Code. It may be noted that the type material of this name was destroyed in World War II (Wulff, 1949).

In 1966 L. Bolus (1966) published a var. parviflorum of G. haagei sensu Schwantes (1938). This variety had somewhat larger flowers than those mentioned in Schwantes' description, despite the varietal epithet.

The present name (austricolum) refers to the fact that this is the only member of the Gibbaeinae to be found south of the Langeberg.

It is found on white patches of clayey sand with or without quartz pebbles on hilltops or steep slopes, without the cover of low shrubs that is characteristic of the natural veld of this area south of the Langeberg. All populations seen were more or less heavily grazed, presumably by sheep. It is interesting to note that species of Glottiphyllum and Acrodon growing socially with this species are not grazed.

Specimens of this species have been misidentified as G. pubescens subsp. shandii, G. esterhuyseniae and G. haagei.

The outstanding character of this rather variable species is that it is found south of the Langeberg. It may resemble a small form of G. velutinum in herbarium specimens, but differs in hair structure, the shape of the leaf apex and the small size and reduced number of all its parts. In the field, plants are often difficult to see, having been eaten off level with the ground. This is a useful distinguishing character of live plants, as no other member of the group is eaten by herbivorous mammals. The leaves are silvery-glaucous,

pale green or grey. The eastern plants seem to have more nearly hemispherical and more nearly equal leaves than those growing at the western end of the range of this species, but plants with a variety of leaf-shapes will be found in any one colony. The extremes are well represented by the type plant and the Van Breda specimen from Witkop.

The type specimen consists of three flowering fragments and a dissected flower. There are three isotypes, all of which have been made up in the same way as the type. These have not been distributed at the time of writing.

11. Gibbaeum album N.E. Br., Gard. Chron. 79:215 (1926); Tisch., Z. Sukkulentenk. 3:227 (1927); N.E. Br., Tisch., Karsten, Mesembryanthema :218 (1931); Jacobsen, Sukk. Pfl. :132 (1933); Jacobsen, Succ. Pl. :178 (1935); Nel, Gibbaeum Handb. :50 - 52 (1953); Jacobsen, Handb. Succ. Pl. 3:1150 (1960); Jacobsen, Sukk. Lex. :425 (1970)

G. album var. roseum N.E. Br., Gard. Chron. 81:430 (1927); Tisch., Z. Sukkulentenk. 3:227 (1927); Jacobsen, Succ. Pl. :178 (1935); near Springfontein, 13 December 1926, fl., Muir 3975 (K!, holotype)

G. album forma roseum (N.E. Br.) Rowley, Nat. Cact. Succ. Jl. 13(4) :77 (1958); Jacobsen, Handb. Succ. Pl. 3: 1151 (1960); Jacobsen, Sukk. Lex. :425 (1970)

Syntypes: Phisantefontein, 29 November 1926, fl., fr., Muir 3093 (K!, BOL!); Ladismith division, February 1927, nf., Muir 3623 (K!)

Plant a dwarf succulent forming clumps up to 10 cm in diameter, usually each stem with only one pair of leaves at a time; leaves opposite, almost hemispherical, conspicuously keeled, glaucous to white, hairy, the larger of each pair 15 - 17 - 21 mm long, 15 - 17 - 22 mm wide and deep, the lesser 9 - 11,5 - 16 mm long, 14 - 17,5 - 20 mm wide, the upper surface much shorter thanthan the lower in both, and more or less hidden in the fissure between the leaves; indumentum of much-branched, unicellular trichomes, the branches interlocking with those of neighbouring trichomes in a distinctive zig-zag pattern; trichomes present on all epidermal cells except the guard cells of stomata. Epidermal cells uniform, hexagonal, 30 - 39 microns in diameter, walls straight, sometimes slightly bowed, outer wall sculptured with fine dots; stomata not visible through the indumentum, aperture 17,5 microns long, guard cells 36 microns long, 7,5 microns wide, subsidiary cells 2 per stoma. Rootstock stout and woody.

Flowers solitary, terminal, ca. 25 mm in diameter; peduncle ebracteate, ca. 7,5 mm long, ca. 4,5 mm wide; sepals 6, equal, 6 mm long, up to 4,5 mm wide; petals biseriate, 50 - 100, 8 - 15 - 21 mm long, up to 1,7 mm wide, white to pink; staminodes staminoid to petaloid along a gradient from the centre of the flower, 75 - 100, 4,5 - 5 - 8 mm long, white; stamens 75 - 100, filaments 4,5 - 8 mm long; styles and stigmas 6, 0,8 - 1,6 - 3,0 mm long. Capsule 6-locular, 5 mm in diameter, 3 mm deep, pale beige; seeds reddish-brown, many in each locule, usually without patterning but sometimes with faint longitudinal ridges, 600 - 800 microns long, 350 - 500 microns wide, 250 - 400 u deep; funicle 200 - 250 u long, usually with close-packed, roughly rectangular to discoid pattern elements. Chromosome number 2n = 18 (Wulff, 1944; de Vos, 1951)

Specimens seen

CAPE: 3320; -DC, Barrydale, November 1927, fl., Ferguson s.n. in NBG 1223/27 (BOL)

-DD, Between Barrydale and Springfontein, May 1932, fl., fr., L. Bolus 20122 (BOL); Uitvluct, October 1926, fr., Muir 3927 (K)

3321; -CA, Between Garcia's Pass and Ladismith, January 1931, fl., fr., L. Bolus s.n. (BOL)

-CC, Between Springfontein and Muiskraal, 6 December 1949, fl., H. Hall s.n. in NBG 1315/49 (K); Muiskraal, 6 December 1953, fl., H. Hall s.n. (BOL); Phisantefontein, 29th November 1926, Muir 3093 (K, syntype); near Springfontein, 13 December 1926, Muir 3975 (K, holotype of synonym)

Without exact locality: Ladismith Division, February 1927, Muir 3623 (K, syntype)

This species grows on white quartz patches and flowers in November to December. In the field the irregular shape of the glaucous leaves, which are keeled, roughly tetrahedral and hairy, render this species distinctive and difficult to confuse with any other. In the herbarium it may be distinguished from all others by the interlocking trichome-branches, and the shape of the leaves.

The name "album", meaning "white", is apt, as the leaves are pale glaucous-blue, almost the same colour as the surrounding white quartz stones in its natural habitat. In most plants the flowers are white, but a pink-flowered form, otherwise indistinguishable from typical G. album, has been described.

Muir 3093 consists of a mounted fragment and two capsules, labelled and cited as the type at Kew. The duplicate at BOL consists of five capsules, each bearing the same number, and one with the word "Type !"

in L. Bolus' handwriting. These capsules contain dissected flowers, fruits and flowering plant fragments.

Muir 3623 consists of two mounted fragments without visible flowers or fruits, labelled and cited as a type in N.E. Brown's handwriting.

12. Gibbaeum nebrownii Tisch., Kakt. und Sukk. 1937 :151 (1937); Nel, Gibbaeum Handb. :64 - 67 (1953); Schutzbach, Nat. Cact. Succ. Jl. 21:94 (1966) (-non G. muirii N.E.Br.)

Imitaria muirii N.E. Br., Jl. Bot. 65:348 (1927); N.E. Br., Tisch., Karsten, Mesembryanthema :239 (1931); von Pöllnitz, Feddes Rep. 33:46 (1933); Jacobsen, Sukk. Pfl. :141 (1933); Jacobsen, Succ. Pl. :190 (1935); Swüste, Succulenta 20:66 (1938); Byrd, Yorkshire Cact. Jl. 1:25 (1946); L. Bolus, Notes Mesemb. allied Gen. 3:388 (1958); Jacobsen, Succ. Pl. 3:1182 (1960); Jacobsen, Sukk. Lex. :434 (1970). Muir 4021, Holotype

Holotype: Dammetjies, Klein Karoo, Montagu Div., April 1927, fl., fr., Muir 4021, (K!)

Plants dwarf succulents, the top surface level with or only slightly above the ground, clumps up to 4 cm in diameter; each stem with one pair of leaves at the tip, and with the remains of old leaves adhering. Leaves opposite, connate for the whole of their length to form a body, with a fissure three quarters of the width of the body or more across the

top; bodies 13 - 21 mm long and 11 - 17 mm in diameter. Indumentum of straight hairs dichotomising in the middle, some dichotomising again near the tips and rarely with a third dichotomy, on all cells except the guard cells and subsidiary cells of the stomata. Epidermal cells all of similar sizes, hexagonal to almost circular, 63 - 78 microns in diameter, radial walls straight to curved, outer wall sculptured with fine lines; stomatal ratio 15,6%, stomatal aperture 11 microns long, guard cells 19 microns long and 6 microns wide, subsidiary cells 2 per stoma. Rootstock moderately stout and woody.

Flowers solitary, up to 16 mm in diameter; peduncle ebracteate, up to 11 mm long, 5,5 mm in diameter below the flower, becoming flattened towards the base, there roughly elliptical, ca. 1,5 mm in minor axis; sepals 6, two larger and fleshier than the rest, the larger up to 6 mm long and 2 mm wide, the rest up to 5 mm long and 1 mm wide; petals 35 - 40, connate at the base to form a tube, pale pink, 11,5 - 14 mm long and up to 1,1 mm wide, triseriate; nonpetaloid staminodes 60 - 70, 2,5 - 4 mm long; stamens 18 - 30, filaments 2 - 5 mm long; styles and stigmas narrowly subulate, 4 - 5 mm long; capsule 6-locular, 4,5 mm in diameter, 2,5 mm deep; seeds pale brown, 520 - 730 microns long, 350 - 490 microns wide and 325 - 460 microns deep, funicle 130 - 370 microns long; surface pattern of hemispherical to elongate humps and wrinkles between these, humps 10 - 14 microns in diameter, 12,5 microns

apart; funicle pattern of hemispherical, elongate or irregular humps 12 - 23 microns in diameter and 3,5 microns apart. Chromosome number 2n = 18 (Wulff, 1944, de Vos, 1951)

Specimens seen

CAPE: 3320; -CB, Dammetjies, April 1927, fl., fr., Muir 4021 (K, holotype)

-DA, Klipgat, May 1932, fl., fr., L. Bolus s.n. in NBG 731/32 (BOL)

-DB, Kareevlakte, 28 April 1953, fl., H. Hall s.n. in NBG 347/53 (BOL); Kareevlakte, 18 June 1974, fr., Glen 806 (BOL)

3321; -AD, Ladismith Karoo, 31 March 1932, fl., Primos s.n. (BOL)

This species shares with Didymaotus lapidiformis the distinction of being the member of the group that is most difficult to see in the field. Plant bodies are the same size, shape and general colouring as the shale pebbles among which they grow. Most plants seen showed evidence of injury which was ascribed to sheep having inadvertently stood on them. In the rainy season the tops of the bodies are level with the surrounding soil; in the dry season the plants sink into the ground and are hidden by a thin layer of dust and debris.

G. nebrownii is unique in the group, in that the petaloid staminodes are fused at the base into a short tube. For this reason it was put into a separate genus, but in view of the results of the present

numerical study, this genus cannot be upheld. In Gibbaeum, the three species that G. nebrownii is most likely to be confused with are G. pilosulum, G. nuciforme and G. dispar. The fissure in G. nebrownii extends the full width of the plant body, unlike that of G. pilosulum and G. nuciforme. The top of the body is flat, unlike the pointed top of G. dispar, and all the hairs are branched.

The type sheet of this species has on it two large plants, three capsules, a printed copy of the original description, and a label in N.E. Brown's handwriting, citing it as the type. One capsule contains a number of fruiting plants, the second two small plants and the third contains a flower.

The genus Imitaria was established by Brown in 1927, with one species, I. muirii. If this species is to be transferred to the genus Gibbaeum, it cannot be called G. muirii, as this name was published by Brown in 1926 for a taxon now considered to be synonymous with G. gibbosum. The combination G. muirii (N.E. Br.) Schwantes (= Mentocalyx muirii N.E. Br.) was made in 1935, as a name for a strain of G. velutinum. The earliest legitimate name for the present species in Gibbaeum is therefore G. nebrownii Tisch., published in 1937.

Section 4. Neogibbaeum Wulff

Neogibbaeum Wulff, Bot. Archiv 45 :169; Jacobsen Handb. Succ. Pl. 3:1150 (1960); et in Sukk. Lex. :425 (1970)

Plants small clump-forming succulents; leaves green, reddish, yellowish, or glaucous, digitiform, shortly triquetrous or keeled-hemispherical. Indumentum absent throughout. Epidermal cells all about the same size. Flowers white, pink or magenta.

Three subsections and three species.

Subsection 4.1 Glabrophyllum Glen, subsect. nov.

Glabrophyllum Glen, subsect. nov.

Muiriopsis Wulff, Bot. Archiv. 45:159 (1944) pro parte, quoad G. gibbosum solum.

Plantae succulentae parvae; folia viridia, rufescentia, vel lutescentia, digitiformia. Indumentum nullum. Cellulae epidermidis omnes quasi pariles. Radix valida, lignosa.

Flores magentei.

Species unica, G. gibbosum.

Plants succulents forming small clumps; leaves green, reddish or yellowish, digitiform. Indumentum absent. Epidermal cells all about the same size. Rootstock stout and woody.

Flowers of medium size, magenta.

Only species, G. gibbosum.

13. Gibbaeum gibbosum (Lettsom ex Haw.) N.E. Br., Gard. Chron. 71:151 (1922); Tischer, Z. Sukkulentenk. 3:227 (1927); Jacobsen, Succ.Pl. :179 (1935); Nel, Gibbaeum Handb. :72 - 80 (1953); Jacobsen, Handb. Succ. Pl. 3:1153 (1960); Jacobsen, Sukk. Lex. :426 (1970)

Mesembryanthemum gibbosum Lettsom, Hort. Upton. :34 (1781), nom. nud.: Haw., Obs. Gen. Mesemb. 2:137, 451 (1795); Haw., Misc. Bot. :36 (1803); Ait. f., Hort. Kew. ed. 2, 3:214 (1811); Haw., Syn. Pl. Succ. 226 (1812); Haw., Rev. Pl. Succ. :104 (1821); DC., Prodr. 3:423 (1828); Don, Syst. Gen. Gard. Bot. 3:131 (1834); Sond., Fl. Cap. 2:404 (1863); Berger, Mesembryanthemen und Portulacaceen :226 (1908). Type not found, probably no longer extant

M. perviride Haw., Obs. Gen. Mesemb. 2:136 (1795); Haw., Misc. Bot. :37 (1803); Ait. f. Hort. Kew. ed. 2, 3:221 (1811); Haw., Syn. Pl. Succ. :227 (1812); Haw., Rev. Pl. Succ. :104 (1821); DC., Prodr. 3:423

(1828); Don, Syst. Gen. Gard. Bot. 3:131 (1834); Sond., Fl. Cap. 2:403 (1863); Berger, Mesembryanthemen und Portulacaceen :227 (1908).
Type not found, probably no longer extant.

M. perviride Haw. var. β Haw., Misc. Bot. :37 (1803).
Type not found, probably no longer extant.

M. luteoviride Haw., Syn. Pl. Succ. :226, 249 (1812), Haw., Rev. Pl. Succ. :104 (1821); DC., Prodr. 3:423 (1828); Don, Syst. Gen. Gard. Bot. 3:131 (1834); Sond., Fl. Cap. 2:402 - 403 (1863); Berger, Mesembryanthemen und Portulacaceen :227 (1908).
Type not found, probably no longer extant.

G. perviride (Haw.) N.E.Br., Gard. Chron. 71:151 (1922); N.E. Br., Gard. Chron. 79:234 (1926); Tisch., Z. Sukkulentenk. 3:227 (1927); Jacobsen, Sukk. Pfl. :133 (1933); Jacobsen, Succ. Pl. :180 (1935)

G. perviride (Haw.) N.E. Br. var. luteoviride (Haw.) N.E. Br., Gard. 71:151 (1922)

G. luteoviride (Haw.) N.E. Br., Gard. Chron. 79:215 (1926); Tisch., Z. Sukkulentenk. 3:227 (1927); Jacobsen, Sukk. Pfl. :133 (1933); Jacobsen, Succ. Pl. :179 (1935); Wulff, Bot. Archiv 45:156 (1944); Jacobsen, Handb. Succ. Pl. 3:1155 (1960); Jacobsen, Sukk. Lex. :426 (1970)

G. muirii N.E. Br., Gard. Chron. 79:216 (1926); Tisch., Z. Sukkulentenk. 3:227 (1927);
Holotype: between Touwsfontein and Allemorgensfontein, Oct. 1925, fl., Muir 3704 (K!)

G. marlothii N.E. Br., Gard. Chron. 84:492 (1928)
Holotype: North of Karoo Poort, 11 December 1927, fl., Marloth 13157 (K!)

Proposed Neotype Touws River, July 1933, fl., Joubert 72 (BOL!)

Plants dwarf succulents forming clumps up to 10 cm in diameter and as tall as the leaves; each stem bearing one or two pairs of leaves at a time; leaves opposite, terete, conical or "double terete", narrowing sharply at the end of the leaf-sheath; leaves connate for ca. 7,5 mm; one leaf of a pair larger than the other, the larger 17 - 36,5 mm long and 6,5 - 14 mm in diameter; leaves emerald green, yellow-green, yellowish or coppery red, depending on the physiological state of the plant; indumentum absent; epidermal cells essentially uniform in size, very variable in shape, rectangular, pentagonal, hexagonal, heptagonal, elliptical, circular or irregular, minor axis 22 - 65 microns, major axis 30 - 71 microns, sculpturing absent to conspicuous, when conspicuous composed of fine irregular lines and many dots; walls straight to strongly curved but not undulate, outer wall flat or humped, sometimes with a short, broad cylindrical projection; stomatal ratio 6 - 10%, stomatal aperture

8 - 15 microns long, guard cells 20 - 24 microns long, and 4 - 5 microns wide; subsidiary cells 2 per stoma. Rootstock stout and woody.

Flower terminal, solitary, 25 - 40 mm in diameter; peduncle 15,5 - 17 mm long, ebracteate, round at the top, diameter 5 - 6 mm, flattened at the base, mean minor axis 3 mm; petals uniseriate or biseriate, 30 - 45, spatulate, 6 - 17 mm long and up to 1,2 mm wide, pink to magenta; sepals 6, two fleshy, the rest with membranous margins, the fleshy ones 4 - 5 mm long and up to 2,8 mm wide, the others 4 - 4,7 mm long and up to 3,2 mm wide; staminodes 14 - 30, 1,5 - 3,4 - 8 mm long; stamens 18 - 75, filaments 1,5 - 3,2 - 6 mm long; styles and stigmas 6, reniform, 0,8 - 1,9 - 2,5 mm long. Capsules 6-locular, 5,5 - 6,5 mm in diameter, 2,5 - 5 mm deep; seeds 500 - 750 microns long, 330 - 500 microns wide and 350 - 520 microns deep, with a 125 - 300 micron-long funicle; pattern on the surface of elongate humps or obscure, the humps widely and irregularly spaced, otherwise the outer cell-walls slightly raised, these with a pattern of irregular ridges and hollows; pattern on the funicle of rectangular or rarely irregular, close packed humps. Chromosome number 2n = 18 or 36 (Wulff, 1944; de Vos, 1951).

Specimens seen

CAPE: 3219; -DC, Skitterykloof, 1 June 1973, fr., Glen 692 (BOL); Spes Bona, November 1932, nf., Nielson s.n. (BOL)

3319; -BD, Hartebeeste Kraal, 29 May 1973, fr., Glen 662 (BOL)

3320; -AC, Touws River, July 1933, fl., Joubert 72 (BOL, neotype); Touws River, May 1944, fl., James s.n. (BOL); Die Bron, 29 May 1973, fr., Glen 664 (BOL)

-BA, Matjesfontein, 1906, fl., Pillans 887 (BOL); Whitehill, 14 August 1925, fl., Archer A54, (BOL); Matjesfontein district, June 1920, fl., Frith s.n. in NBG 1390/19; 10 miles from Laingsburg, 18 May 1934, fr., Logan s.n. in BOL 21641 (BOL)

-BB, Between Laingsburg and Sutherland, no date, fl., Joubert 77 (BOL); Laingsburg, 20 August 1934, fl., Anon. s.n. in SUG 10408 (BOL); Laingsburg, 29 August 1939, fl., Wilmot s.n. (BOL)

-CA, between Montagu and Touws River, October 1933, fr., Lewis s.n. in NBG 2029/33 (BOL); near Paardefontein, no date, fl., Muir 4027 (K); Nougas Poort, 29 May 1973, fr., Glen 661 (BOL); north-east of Nougas Poort, 29 May 1973, fr., Glen 663 (BOL)

-CB, between Touwsfontein and Allemorgensfontein, October 1925, fr., Muir 3704 (K)

-DA, Kareevlakte, 29 June 1948, fr., Acocks 14574 (BOL)

Without locality: September 1933, fr., Wonfor s.n. in NBG 1605/33 (BOL)

Garden material: hort. Miss Arbuthnot, 9 August 1928, fl., Cook 1924 (BOL); hort N.E. Brown, January 1922, fl., Anon. s.n. (K)

Spirit material: 3320AC, Touws River, August 1928, nf., Cook s.n. (BOL); without locality, no date, nf., Anon. s.n. in STE-U 660 (STE-U)

This is the commonest Gibbaeum with digitiform, glabrous leaves. It is distinguished from Antegibbaeum fissoides by having one leaf of a pair much larger than the other and by having neither bracts nor ecninate seeds. It differs from G. pubescens subsp shandii, which it strongly resembles in the shape, size and colour of its leaves, in being glabrous.

G. gibbosum is not specific in its edaphic requirements, occurring indiscriminately on yellow sand, white quartz or shale. Although the colouring of the leaves is very variable, and an attempt has been made (Haworth, 1795) to erect species on this, it appears that this variability is a product of light intensity and water content, and has no significance.

A tetraploid strain of this species has been recorded (Wulff, 1944). The field character used to distinguish this strain from the diploid strain is a difference in leaf-colour that is also indicative of drought at relatively low light (heat?) intensity or terminal fungus infection or possibly mineral deficiency.

The epidermal cells are said to differ in size between the two strains, but the size ranges of the two strains overlap and the difference is not significant.

Under the name M. gibbosum, Haworth describes a plant which has "scarcely two (leaves) of equal sizes on the whole plant, one of a pair always larger, longer and more gibbous than the other, few of them more than one inch long, all of them more or less blunt, compressed, oblique and gibbous." When he wrote the first description he had not seen a flower, but later descriptions make it quite clear that the plant in question belongs to the genus Gibbaeum. He observes that M. perviride (now considered to be conspecific with G. gibbosum) is "a new species resembling (M) fissum, and (M) gibbosum, intermediate, but extremely distinct.".

M. fissum is now known as Argyroderma fissum, and as there are no hairy Argyrodermas, we may deduce that M. perviride and M. gibbosum are glabrous. Weight is lent to this hypothesis by his description of M. pubescens as having "leaves, in shape and habit, much resembling those of perviride, but closely covered with ... hoary pubescence...".

Summarising the above, G. gibbosum is a plant with glabrous, unequal leaves, about an inch (25 mm) long. Two species of the Gibbaeinae match this description; Antegibbaeum fissoides and G. gibbosum. The former species was known to Haworth as M. fissoides, and a plate of the plant grown at Kew was made. This plate is clearly identifiable as A. fissoides.

It was deduced in section 2 of the present work that the locality from which Haworth's plant of G. gibbosum originated, was near Touws River. A desirable specimen for proposition as a neotype, therefore, would be one from the same area. One of the best specimens in the Bolus Herbarium, Joubert 72, is from this area and is therefore proposed as the neotype of this species. This specimen consists of three capsules, one containing a mounted fragment with fruit and the other two with dissected leaves and flowers.

Subsection 4.2 Argeta (N.E. Br.) Wulff

Argeta (N.E. Br.) Wulff, Bot. Archiv 45:169 (1944); Jacobsen, Handb. Succ. Pl. 3:1150 (1960); et in Sukk. Lex. :425 (1970)

Argeta N.E. Br., Gard. Chron. 82:114 (1927) pro. gen.; N.E. Br. in Jl. Bot. 66:265 (1928); Tischer, Monatsschr. D. Kakt. Gess. 1:234 (1929); N.E. Br., Tisch., Karsten, Mesembryanthema :258 (1931); Jacobsen, Sukk. Pfl. :90 (1933); Von Poellnitz, Feddes Rep. 33:26 (1933); Jacobsen, Succ. Pl. :125 (1935); Goossens, Blompl. :146 (1940)

Small succulents forming low clumps; leaves connate at the base, slightly divergent, almost deltoid to strongly keeled-hemispherical, apices with a "chin" or squared. Indumentum none. Epidermal cells all about the same size. Flowers small for the genus, magenta to purple.

One species: G. petrense (N.E. Br.) Tisch.

14. Gibbaeum petrense (N.E. Br.) Tisch., Kakt. und andere Sukk. 1937 :151 (1937); Nel, Gibbaeum handbook :56 (1953); Jacobsen, Handb. Succ. Pl. 3:1156 (1960); et in Sukk. Lex :426 (1970)

Argeta petrensis N.E. Br., Gard. Chron. 82:114 (1927); N.E. Br., Jl. Bot. 66:265 (1928); L. Bol., S. Afr. Gard. Country Life 19:221 (1928); N.E. Br., Tisch., Karsten, Mesembryanthema :108 (1931); Von Poellnitz, Feddes Rep. 31:26 (1933); Jacobsen, Sukk. Pfl. :90 (1933); Jacobsen, Succ. Pl. :126 (1935); Muir 3622 (K!, holotype: BOL! isotype)

G. tischleri Wulff, Sukkulentenkunde (Zürich) 3:55 (1949); Jacobsen, Handb. Succ. Pl. 3:1157 (1960); Jacobsen, Sukk. Lex. :427 (1970)
Type not stated in the protologue

G. haagei Schwant. ex Jacobsen, Succ. Pl. :179 (1935), nom. illegit.

Holotype: Derde River, September 1925, fl., fr., Muir 3622 (K!)

Plants forming clumps or mats up to 25 cm in diameter, each stem with up to three pairs of leaves, and old leaf bases persisting along its length; leaves opposite, tetrahedral to deltoid in longitudinal section and reniform in transverse section, very conspicuously keeled, one of each pair slightly larger than the other, the larger 9 - 20 mm long and 6 - 11 mm wide, the smaller 9 - 13 - 19 mm long and 6 - 11 mm wide, the larger usually with a "chin"-shaped apex and the smaller

usually with a squared apex, leaves glabrous and glaucous-grey, except after rain or in cultivation, then grey-green. Indumentum none. Epidermal cells hexagonal, 28 - 53 mm in diameter, walls undulate, sculpture of fine lines on the outer wall; stomatal ratio 3 - 8%, stomatal aperture 15,5 microns long, guard cells 22,5 microns long and 9 microns wide, stomata without differentiated subsidiary cells. Rootstock composed of a taproot and many lateral roots.

Flowers terminal, solitary, 20 - 30 mm in diameter, peduncle 7,5 - 8 mm long, 4 mm in diameter; sepals 6, two large and fleshy, the rest smaller, with membranous margins, the larger ones up to 4,7 mm long and 2,5 mm wide, the smaller ones up to 4 mm long and 2 mm wide; petaloid staminodes biseriate, 35 - 40, 13 - 16 mm long, up to 1,3 mm wide, magenta; nonpetaloid staminodes 30 - 50, 2,5 - 4,5 mm long; stamens 80 - 90, filaments 1 - 3,4 - 4,5 mm long; styles and stigmas 6, 2 - 4 mm long, narrowly subulate. Capsule 6-locular, 4 mm in diameter, 3,5 mm deep; seeds ca. 570 - 790 microns long, 350 - 500 microns wide and 250 - 350 microns deep, ovoid, with a funicle 250 - 300 microns long, many seeds with a ca. 90 micron-long tubercle next to the funicle; surface pattern of close-packed discoid to hemispherical elements or faint to distinct longitudinal ridges, or surface without pattern, all possibilities sometimes occurring on the same seed; funicle pattern of rectangular to irregular elements, close packed.

Pollen grains separate, spherical, ca. 15 microns in diameter, tricolpate, colpi extending the length of the grain, ca. 0,5 - 1 micron wide; ektexine pitted and with projections, these hemispherical to cylindrical.

Chromosome number 2n = 18 or 36 (Wulff, 1944; de Vos, 1951)

Specimens seen

CAPE: 3321; -CA, Ladismith, 13 October 1932, fl., fr., Joubert 41 (BOL); near Ladismith, November 1928, nf., Gillett s.n. (BOL)

-CC, Springfontein, June 1932, fr., L. Bolus s.n. in NBG 709/32 (K); between Brand River and Springfontein, 19 May 1973, fr., Glen 639 (BOL); Springfontein 16 June 1974, fr., Glen 805 (BOL)

-CD, Derde River, September 1925, fl., fr., Muir 3622 (K, holotype BOL, isotype)

3421; -AD, Still Bay, January 1931, fr., L. Bolus s.n. (BOL)

Without precise locality: Little Karoo, January 1944, fl., Minnaar s.n. (BOL)

Garden plants: Hort. L. Bolus, 5 May 1928, fl., L. Bolus s.n. (K); hort. Ross Frames, 25 September 1937, fl., P. Ross Frames s.n. (BOL); Stellenbosch Hortus Botanicus, 26 January 1955, fl., Stellenbosch Hort. Bot. s.n. (BOL)

Gibbaeum tischleri is said to differ from G. petrense in being tetraploid, and in the shape of the leaf tips, the former having a "chin"-shaped apex to the leaf and the latter a squared-off apex. However, a study in the field shows that most plants have leaves of both forms on the same plant, often in the same pair. In view of this, and the minute quantitative differences between plants given the two names, it has been decided to regard G. tischleri as a synonym of G. petrense.

The L. Bolus specimen noted as having been collected at Still Bay (3421 AD) is probably a labelling error on the specimen in question. It is known (O'Connor-Fenton, pers. comm.) that Mrs. Bolus spent January 1931 at Still Bay on holiday with a friend. In view of the fact that the duplicate of L. Bol. 19861 (Muiria hortenseae) at Kew has the locality information "Still Bay" deleted and "Springfontein" inserted in L. Bolus' handwriting, and that G. petrense and M. hortenseae grow socially at this locality, it seems reasonable to deduce that the specimen in question was, in fact, collected within one kilometre of the locality of Glen 805, and not at Still Bay, as claimed on the label.

G. petrense is distinguished from all other members of the group by its small, strongly keeled, glabrous leaves. Plants flower in July-August.

The type specimen of this species is in two parts, both mounted on the same sheet and cited as the type in N.E. Brown's handwriting. The first comprises two capsules of fruits, evidently collected in the field.

The second comprises a capsule containing dissected flowers and a mounted fragment, and is labelled "from my type plant / Hort. N.E. Brown", in Brown's handwriting.

Subsection 4,3 Rimaria (N.E. Br.) Wulff

Rimaria (N.E. Br.) Wulff, Bot. Archiv. 45:172 (1944); Jacobsen, Handb. Succ. Pl. 3:1150 (1960); et in Sukk. Lex. :425 (1970)

Rimaria N.E. Br., Gard. Chron. 78:413 (1925) in clav., N.E. Br., in Gard. Chron. 79:85,134 (1927) pro gen., partim; Tisch., Z. Sukkulentenk. 3:226 (1928); N.E. Br., Gard. Chron. 81:85 (1929); Jacobsen, Sukk. Pfl. :173 (1933); Von Poellnitz, Feddes Rep. 32:64 (1933); Jacobsen, Succ. Pl. :240 (1935); Goossens, Blompl. :147 (1940)

Small succulents forming small clumps; leaves connate for about half their length, hemispherical, not keeled. Indumentum absent. Epidermal cells all about the same size. Rootstock stout and woody. Flowers white.

One species, G. heathii.

15. Gibbaeum heathii (N.E. Br.) L. Bol., Notes Mesemb. allied Gen. 3:65 (1937); Nel, Gibbaeum Handb. :36 - 48 (1953); Jacobsen, Handb. Succ. Pl. 3:1153 (1960); Jacobsen, Sukk. Lex. :426 (1970)

Mesembryanthemum heathii N.E. Br., Jl. Linn. Soc. Bot. 45:67 (1920); Karsten, Onze Tuinen 20:222 (1925); Pillans 890, holotype. (K!)

M. fissum sensu N.E. Br., non Haw., Jl. Linn. Soc. Bot. 45:67 (1920)

Rimaria heathii (N.E. Br.) N.E. Br., Gard. Chron. 79:135 (1926); Tisch., Möll. D. Gärt. Zeit. 1926 (28) :342 (1926); Karsten, Succulenta 12:24 (1930); West, Jl. Cact. Succ. Soc. Amer. 1:207 (1930); N.E. Br., Tisch., Karsten, Mesembryanthema :289 (1931); Jacobsen, Sukk. Pfl. :174 (1933); Jacobsen, Succ. Pl. :240 (1935); Pillans 890, holotype. (K!)

R. dubia N.E. Br., Gard. Chron. 79:155 (1926); Karsten, Succulenta 12:27 (1930); West, Jl. Cact. Succ. Soc. Amer. 1:208 (1930); Jacobsen, Succ. Pl. :240 (1930) - Hort. N.E. Brown, March 1926, fl., Anon, s.n. (K!)

G. luckhoffii L. Bol., Notes Mesemb. allied Gen. 2:232 (1932); L. Bol., Notes Mesemb. allied Gen. 3:65 (1937); Jacobsen, Handb. Succ. Pl. 3:1153 (1960); Jacobsen, Sukk., Lex. :426 (1970) - foot of the Little Swartberg, October 1930, fl., J. Luckhoff s.n. in BOL 19393 (BOL!, holotype)

R. luckhoffii (L. Bol.) L. Bol. Notes Mesemb. allied Gen. 2:368 (1932) - Luckhoff s.n. in BOL 19393 (BOL!), holotype

R. comptonii L. Bol., Notes Mesemb. allied Gen. 2:369 (1932); Herre, Kakteenkunde 1934:55 (1934) - Kareevlakte, November 1931, nf., Compton s.n. in NBG 2324/31 (BOL!, holotype)

R. heathii var. major L. Bol., S. Afr. Gard. Country Life 22:331 (1932) - 25 miles South of Ladismith, October 1932, fl., Luckhoff s.n. in BOL 20811 (BOL!, holotype)

R. heathii var. elevata L. Bol., S. Afr. Gard. Country Life 22:331 (1932) - between Warmbaths and Bellair Dam, Platte Kloof and Bakoven, May 1932, fl., L. Bolus s.n. in NBG 771/32 (BOL!, holotype)

G. blackburnii L. Bol., Notes Mesemb. allied Gen. 3:65 (1937) Jacobsen, Handb. Succ. Pl. 3:1151 (1960); Jacobsen, Sukk. Lex. :425 (1970) - near Calitzdorp, September 1936, fl., fr., Blackburn s.n. in BOL 21819 (BOL!, holotype)

G. comptonii (L. Bol.) L. Bol., Notes Mesemb. allied Gen. 3:65 (1937); Jacobsen, Succ. Pl. :179 (1935); Jacobsen Handb. Succ. Pl. 3:1151 (1960); Jacobsen, Sukk. Lex. 425 (1970) - Compton s.n. in NBG 2324/31 (BOL!) holotype

G. heathii var. major (L. Bol.) L. Bol., Notes Mesemb. allied Gen. 3:65 (1937); Herre, Kakt. und andere Sukk. 1937:152 (1937); Jacobsen, Handb. Succ. Pl. 3:1153 (1960); Jacobsen, Sukk. Lex. :426 (1970) - Luckhoff s.n. in BOL 20811 (BOL!) holotype

G. heathii var. elevata (L. Bol.) L. Bol., Notes Mesemb. allied Gen. 3:65 (1937): Jacobsen, Handb. Succ. Pl. 3:1153 (1960); Jacobsen, Sukk. Lex. :426 (1970) - L. Bolus s.n. in NBG 771/32 (BOL!, holotype)

Holotype: Between Garcia's Pass and Ladismith, 1906, fr., Pillans 890 (K!), vide infra.

Plant a small succulent, forming clumps up to 10 cm in diameter, each stem with two to three pairs of leaves at a time, the older pairs imbricated around the most recent and partly enclosing it. Leaves opposite, hemispherical to hemi-ellipsoid, very slightly keeled or more often not keeled at all, glaucous, white or reddish, becoming pale green and much larger under cultivation if over-watered or kept in the shade, glabrous, leaves of a pair almost or exactly the same size, (16 -) 18 - 33 - 70 mm long and 7 - 23 - 55 mm in diameter; indumentum absent; epidermal cells uniform, pentagonal to heptagonal, rarely square, 30 - 58,4 microns in diameter, outer wall usually without sculpturing, rarely with a few fine dots, walls straight; stomatal ratio 1,2 - 3,4 - 6,9%, stomatal aperture 13 - 17 microns long, guard cells 25,5 - 28,5 microns long and 5 - 7 - 10,5 microns wide; subsidiary cells 2 per stoma or rarely absent. Rootstock variable, from a mass of fusiform roots to a stout and woody taproot.

Flowers terminal, solitary, 20 - 28 - 30 mm in diameter; peduncle ebracteate, 4 - 22,5 mm long, elliptical in section, becoming flattened at the base and circular at the top, major axis 3 - 8,5 mm, minor axis 2 - 4,2 - 5,4 mm; sepals 7, rarely 6, two fleshier and slightly larger than the rest, the other four or five with membranous margins, the fleshier ones 7 - 9 - 12,5 mm long and 4 - 6 - 10 mm wide, the others 5,5 - 8 - 12,5 mm long and 2,7 - 5,5 - 9,5 mm wide; petals 50 - 110, 2 - 4-seriate, white to pale pink, 6 - 19 mm

long, spatulate, up to 1,5 mm wide; staminodes absent or up to 40, up to 12 mm long; stamens 50 - 105 - 195, filaments 4 - 6,5 - 12 mm long; styles and stigmas usually 8, rarely 7 or 9, subulate, 2 - 5 - 7 mm long. Capsule 8-locular, rarely 7- or 9-locular, 6 - 22 mm in diameter, 3,5 - 7 mm deep, pale beige; seeds maroon-, reddish or neutral brown, 450 - 770 microns long, 400 - 520 microns wide and 180 - 300 microns deep, ovoid with a 170 - 260 micron long funicle and sometimes a tubercle next to the funicle; surface pattern variable on each seed, of longitudinal ridges or furrows, or close-packed elongate, discoid, cylindro-conical, hemispherical, reniform or irregular elements, funicle pattern likewise variable, of rectangular, triangular, elongate, elliptical or irregular elements.

Chromosome number 2n = 18 (Wulff, 1944; de Vos, 1951)

Specimens seen:

CAPE: 3320; -AC, Touws River, no date, fl., Herre s.n. (BOL)

-BA, Whitehill, 14 October 1925, fl., Archer 73 (BOL)

-BB, 3 miles north of Laingsburg, September 1933, fl., fr., Logan s.n. (BOL); between Laingsburg and Sutherland, 24 September 1931, fl., Archer s.n. in NBG 1767/31 (BOL); 4,5 miles north of Laingsburg, 18 May 1934, fr., Logan s.n. (BOL, K); 5 miles from Laingsburg, April 1953, fr., Villet s.n. (BOL)

-BD, Witvlakte, February, 1932, fl., Compton s.n. in NBG 223/32 (BOL); 38 miles northwest of Ladismith, 20 October 1930, fl., Luckhoff s.n. in NBG 1963/30 (BOL, holotype of G. luckhofii); 20 miles from Ladismith, 26 September 1932, fl., Lewis s.n. in NBG 2730/32 (BOL)

-DB, Kareevlakte, November 1931, fr., Compton s.n. in NBG 2324/31 (BOL, holotype of G. comptonii); Klipgat, May 1932, fl., fr., L. Bolus s.n. in NBG 729/32 (BOL, K); Kareevlakte, 20 October 1932, fl., Luckhoff s.n. (BOL); Kareevlakte, 17 October 1932, fl., Anon. s.n. in S.U.G. 9810 (BOL); Hondewater, 14 October 1925, fl., Muir 3777 (K); south of Touwsberg, April 1920, fr., Pole Evans 6926 (K); Hondewater, September 1925, fl., Muir 3665 (K); between Warmwaterberg and Bellair Dam, 7 October 1973, fl., Glen 704 (BOL); between Warmwaterberg and Bellair Dam, 7 October 1973, fr., Glen 705 (BOL)

-DC, 10 miles from Barrydale, 11 August 1955, fr., R. du Plessis 106 (BOL)

-DD, Lemoenshoek, 7 October 1973, fl., Glen 703, (BOL); between Warmwaterberg and Barrydale, 7 October 1973, fl., Glen 707 (BOL)

3321; -AD, Ladismith, October 1936, fl., Jordaan 1786 (BOL); Ladismith, October 1932, fl., Jordaan 11A (BOL); Ladismith, October 1927, fl., Ross Frames s.n. in NBG 2556/27 (BOL);

south of Ladismith, 28 October 1932, fl., Compton s.n. in NBG 225/32 (BOL); Ladismith, June 1927, fr., Frith s.n. in PRE 13440, (PRE)

-CB, Vanwyksdorp, 15 October 1932, fl., Bain s.n. in NBG 2496/31 (BOL); between Ladismith and Laingsburg, 11 August 1963, fr., Rycroft 2717 (NBG)

-CC, Phisantefontein, July 1925, fr., Muir 3093 (A?) (K); 20 miles from Ladismith, 1 October 1948, fl., Kramer 197 (PRE); 17 miles from Ladismith, 30 September 1968, fl., Hardy 321 (PRE); Ockertskraal, 19 May 1973, fr., Glen 637, (BOL)

-CD, Plattekloof, May 1932, fl., L. Bolus s.n. in NBG 771/32 (BOL, holotype of var. elevata)

-DA, Caltizdorp, 1 November 1933, fl., Blackburn s.n. in NBG 2344/33 (BOL, holotype of G. blackburnii); Calitzdorp, 8 June 1935, fr., Blackburn s.n. in NBG 1363/35 (BOL); Calitzdorp, 17 September 1936, fl., Blackburn s.n. (BOL); Calitzdorp Warmbad, 31 January 1955, nf., R. du Plessis 70B (BOL); Calitzdorp, 25 August 1932, fl., Oddie s.n. in NBG 1713/32 (BOL); 10 miles south of Calitzdorp, 27 May 1973, fr., Glen 667 (BOL); Calitzdorp, 30 July 1955, fl., fr., R. du Plessis 70A (BOL)

Without precise locality: October 1932, fl., Joubert s.n. (BOL); Little Karoo, 29 September 1936, fl., Villet s.n. (BOL); October 1926, fl., Muir 3415 (BOL, K); Klein Karoo, February, 1958, fr., Lavranos GN12814 (PRE); Little Karoo, 12 October 1944, Minnaar s.n. (BOL)

Garden material: Hort. Frames, 28 October 1932, fl., P. Ross Frames s.n. in BOL 20813 (BOL); hort. N.E. Brown, 1925, fl., N.E. Brown s.n. (K); hort. Dorée, May 1917, fl., N.E. Brown s.n. (K, holotype); hort. Luckhoff, 10 September 1931, fl., Luckhoff s.n. in BOL 20811 (BOL, holotype of var. major)

Spirit material: 3321DA, Calitzdorp, no date, nf., Blackburn 13 (BOL); Klein Karoo, no date, nf., Anon. s.n. in STE-U 658 (STE-U)

The only other glabrous Gibbaeum with hemispherical leaves if G. nuciforme, which, however, has a fissure which only extends part-way across the top of the body, not right across as in G. heathii. Although very variable, for which reason a number of names have been applied to this species, it is nonetheless very distinctive.

In the field it was noted that the variation within any population is great enough to include more than one of the former "species" in this complex. Therefore, despite the apparent difference between some of the extremes (e.g., G. luckhoffii and the rest),

it is advisable to regard them all as one variable species rather than a number of almost indistinguishable taxa.

In the discussion appended to the original description of M. heathii, Brown states "Living plants of this species were sent in 1906 by Mr. N.S. Pillans to Kew, where they unfortunately soon died; a seed-pod on one of them was, however, given to Dr. F.H. Rodier Heath, after whom I have much pleasure in naming it, and who succeeded in raising a number of plants from the seeds and has subsequently distributed several of them."

The living plants are cited in the description as the type, but the specimen labelled as the type at Kew is cited as originating from "Hort. Dorée". In view of the above, one deduces that these plants are some of the seedlings mentioned in the extract above.

The type sheet is composed of five non-flowering fragments, a capsule containing a dissected flower and three pencil drawings by N.E. Brown. It is labelled "Type specimen !" in Brown's handwriting.

6.2 A N T E G I B B A E U M

Antegibbaeum Schwantes, Bot. Archiv 45:154 (1944); Jacobsen, Handb. Sukk. Pfl. 3:1161 (1955); Schw., Fl. Stones :170, 340 (1957); L. Bol., Notes Mesemb. allied Gen. 3:235 (1958); Jacobsen, Handb. Succ. Pl. 3:985 (1960); Jacobsen, Sukk. Lex. :359 (1970); Herre, Gen. Mesemb. :162 (1971)

Dwarf succulents forming clumps ca. 12 cm in diameter; each stem with one to three pairs of leaves; Leaves opposite, triquetrous to semiterete, one of a pair slightly larger than the other, the larger 15 - 22,5 - 36 mm long and 4 - 8 mm in diameter, the lesser 15 - 20 - 29 mm long and 3 - 8 mm in diameter, bright green, grass-green or slightly reddish. Indumentum absent; epidermal cells uniform, rectangular to hexagonal, 22,5 - 50 microns in diameter, walls straight, strongly bowed or sometimes slightly undulate; outer walls without sculpturing; stomatal ratio 9%, stomatal aperture 11 microns long, guard cells 20,5 microns long and 4,5 microns wide, subsidiary cells 2 per stoma. Rootstock very stout and woody.

Flowers solitary, up to 45 mm in diameter; peduncle with one pair of 8,4 mm long, 3 mm wide bracts, 20 mm long, 2,5 - 5,5 mm in diameter; sepals 6, four with membranous margins, two without, all up to 7 mm long and 4,5 mm wide. Petals 20 - 50, uniseriate, 15 - 28 mm long and up to 2,2 mm wide, deep purple; non-petaloid staminodes absent; stamens 50 - 170, white, filaments 2,5 - 5 - 6,5 mm long; styles and stigmas 6,

subulate, 1,5 - 6 mm long. Capsules 6-locular, the top raised above the disc, 12 mm in diameter and 10 mm deep, dark grey-brown. Seeds approximately tetrahedral, echinate, nearly black, 0,73 - 1,69 mm long, 0,54 - 1,20 mm wide and 0,48 - 1,13 mm deep; spines short and bulbous near the funicle (there is no other sign of the funicle), elsewhere up to 250 microns long, with bases 40 - 60 microns in diameter, 23 microns apart; the whole surface, both on and between spines, covered with minute cylindrical projections.

Chromosome number 2n = 18 (Wulff, 1944; de Vos, 1951)

This genus is monospecific.

Antegibbaeum fissoides (Haw.) Schwantes, in Wulff, Bot. Archiv 45:154 (1944); Jacobsen, Handb. Succ. Pl. 3:985 (1960); Jacobsen, Sukk. Lex. :359 (1970)

Mesembryanthemum fissoides Haw., Obs. Gen. Mesembryanthemum 2:135 (1795); L. Bol., S. Afr. Gard. Country Life 18:279 (1928) anonymous painting at Kew, iconotype

M. obtusum Haw., Misc. Nat. :25 (1803); Ait. f., Hort. Kew. ed 2, 3:214 (1811); Haw., Syn. Pl. Succ. :206 (1812), Haw., Rev. Pl. Succ. :86 (1821); DC., Prodr. 3:418 (1828); Don, Syst. Gen. Gard. Bot. 3:127 (1834); Sond., Fl. Cap. 2:394 (1863); Berger, Mesembryanthemen und Portulacaceen :273 (1908); N.E. Br., Jl. Linn. Soc. Bot. 45:74 (1920); anonymous painting at Kew, iconotype

M. divergens Kensit, Trans Roy. Soc. S. Afr. 1:151 (1909) - Matjesfontein, 1905, fl., Pillans 949 (BOL, holotype)

Gibbaeum nelii Schwantes ex Jacobsen, Sukk. Pfl. :133 (1933); Jacobsen, Succ. Pl. :180 (1935) Type not cited

G. fissoides Nel, Gibbaeum Handb. :81 - 82 (1953) comb. illegit. (no basionym cited)

Iconotype: unpublished, anonymous plate at Kew (!); copy published by N.E. Brown (1920)

Description as for the genus.

Specimens seen

CAPE: 3320; -BA, Matjesfontein, 1905, fl., Pillans 949 (BOL, holotype of M. divergens)

-BB, Laingsburg, October 1931, fr., Bain s.n. (BOL)

-BD, between Ladismith and Laingsburg, September 1917, fl., Pillans 1287 (BOL)

-CB, Eyer Poort, September 1935, fr., E. Esterhuysen s.n. (BOL)

-DB, 10 miles west of Kareevlakte, 19 March 1973, fr., Glen 580 (BOL); 6 miles west of Kareevlakte, 19 March 1973, fr., Glen 582 (BOL)

-DC, Barrydale, October 1932, fr., Helm s.n. in NBG 1726/32 (BOL); Barrydale, September 1923, fl., Lewis s.n. in NBG 355/19 (BOL)

-DD, 7 miles from Warmwaterberg, 1 August 1955, fl., R. du Plessis 115 (BOL); Lemoenshoek, 7 October 1973, fr., Glen 702 (BOL)

3321; -AD, near Ladismith, July 1931, fr., Primos s.n. (BOL)

-CC, near Muiskraal, 23 August 1943, fl., Chisholm s.n. in NBG 823/38 (BOL); 5 miles from Muiskraal, 26 August 1944, fl., Minnaar s.n. in BOL 23138 (BOL)

-DD, Kruidfontein, September 1923, fl., Lamb s.n. in NBG 3234/14 (BOL)

3322; -AA, Prince Albert Division, January 1925, fl., fr., Leipoldt s.n. in NBG 110/25 (BOL)

3420; -AB, Swellendam, September 1928, fr., Van der Merwe s.n. (BOL)

Without exact locality: Klein Karoo, August 1928, fl., fr., Ferguson s.n. (BOL)

Garden specimen: Bonnievale, July 1933, fl., Hurling and Niel 1 (BOL)

Spirit material: no locality, 6 August 1945, fl., Anon. s.n. in STE-U 651 (STE-U)

A. fissoides is distinguished from all other species in this subtribe by its echinate seeds and the fact that the valves of the capsule are arched when closed. Additional diagnostic characters are the bracts on the peduncle and the digitiform, glabrous leaves. A useful confirmatory character is that the valves of a ripe, closed capsule are separated by a conspicuous

gap, a feature found in no other species in the group. All these characters are visible both in herbarium specimens and in the field.

This species is found throughout the western Little Karoo, growing on shallow to deep soils on shale and quartz. It flowers in August - September.

Nel wrote the manuscript of the section of his book (Nel, 1953) in which he reduces Antegibbaeum to synonymy under Gibbaeum before 1950, the year of his death. At that time a new combination could be validated by an oblique reference to a basionym, but since 1st January 1953 (Stafleu et al., 1972) a full citation has been needed. Nel's book was not completed at the time of his death, and only appeared during the course of 1953. Therefore, the proposed transfer to Gibbaeum was not valid.

A. fissoides appears to be the only member of the group that was known to Haworth, of which material that was available to him is still extant. This material is a watercolour plate of a non-flowering plant that was cultivated under unsuitable conditions. Evidence for this is given by the luxuriant growth and deep green colour of the plant. The plate is labelled "March 22 1825 ... Mesembr:obtusum Haw." in contemporary handwriting. It is annotated "flowers bright reddish.... M. fissoides Haw. Obs. Mesembr. p. 135" in N.E. Brown's handwriting and "Gibbaeum nelii Schw." in an unknown hand.

6.3 D I D Y M A O T U S

Didymaotus N.E. Br., Gard. Chron. 78:433 (1925), nom. nud.; N.E. Br., Gard. Chron. 80:149 (1926); L. Bol., Notes Mesemb. allied Gen 1:43 (1928); Karsten, Succulenta 11:26 (1929); N.E. Br., Tisch., Karsten, Mesembryanthema :204 (1931); Von Pöllnitz, Feddes Rep. 32:38 (1933); Jacobsen, Sukk. Pfl. :122 (1933); Pax & Hoffmann, Natürl. Pflanzenfam. 16c:214 (1934); Jacobsen, Succ. Pl. 165 (1935); Phillips, Gen. S. Afr. Fl. Pl. ed. 2 :320 (1951); Jacobsen, Handb. Sukk. Pfl. 3:1327 (1955); Schwantes, Fl. Stones :170 (1957); Jacobsen, Handb. Succ. Pl. 3:1109 (1960); Jacobsen, Sukk. Lex :410 (1970); Herre, Gen. Mesemb. :130 (1971)

Mesembryanthemum L. sect. Aloidea Haw., sensu Marl., Trans. Roy. Soc. S. Afr. 4:137 (1914), pro parte

Small succulents, each plant usually existing for most of the year as rootstock, one pair of leaves and two pairs of conspicuous lateral bracts, rarely occurring as "multiple-headed" plants with more than one pair of leaves, then each pair of leaves borne on a separate branch. Leaves opposite, connate at the base to form a short sheath, hemispherical to hemi-ovoid, the abaxial surface much longer than the adaxial surface, very markedly keeled, leaves of each pair about the same size, 25 - 40 mm long and 20 - 27,5 - 40 mm in diameter. Indumentum none, the epidermis normally being covered with wax. Epidermal cells rounded-hemispherical in outline, uniform in size, 15 - 35 microns in diameter,

outer wall sculptured with rounded lumps; stomatal ratio 10%, stomatal aperture 11 microns long, guard cells ca. 18 microns long and 5,5 microns wide, subsidiary cells two per stoma. Roots fusiform.

Flowers solitary, but inflorescences in pairs, these lateral, one at each end of the fissure between the leaves. Peduncle usually S-curved, ca. 25 mm long and 2 - 4 mm in diameter, with a pair of bracts which are conspicuous for many months before anthesis, the bracts ca. 11 mm long and 8 mm wide, shaped like miniature leaves; sepals 6, all the same size, up to 6,5 mm long and 4 mm wide; petaloid staminodes 4-seriate, ca. 100, very pale pink, 11 - 18 mm long and up to 1,1 mm wide; nonpetaloid staminodes none; stamens ca.130, filaments bright pink to magenta, 1,5 - 6 mm long; anthers yellow; styles and stigmas subulate, 1 - 4 mm long. Capsule 6-locular, 11 mm in diameter and 6,5 mm deep; seeds pale red-brown, 525 - 750 microns long, 420 - 600 microns wide and 350 - 450 microns deep, with a 125 - 325 micron-long funicle; pattern on the surface of irregular, tessellate elements irregularly arranged; pattern on the funicle of rectangular to irregular elements, tessellate in irregular rows.

Chromosome number 2n = 18 (Wulff, 1944)

This genus is monospecific.

Didymaotus lapidiformis (Marl.) N.E. Br., Gard. Chron. 80:149 (1926); L. Bol. Notes Mesemb. allied Gen. 1:43 (1928); Karsten, Succulenta 11:27 (1929); L. Bol., S. Afr. Gard. Country Life 19:221 (1929); N.E. Br., Tisch., Karsten, Mesembryanthema :204 (1931); Jacobsen, Sukk. Pfl. :122 (1933); Jacobsen, Succ. Pl. :165 (1935); Jacobsen, Handb. Sukk. Pfl. 3:1327 (1955); Jacobsen, Handb. Succ. Pl. 3:1109 (1960); Jacobsen, Sukk. Lex. :410 (1970)

Mesembryanthemum lapidiforme Marloth, Trans. Roy. Soc. S. Afr. 4:137 (1914); Schwantes, Z. Sukkulentenk. 1:10 (1923)

Holotype: Karoopoort, September 1913, fl., Marloth 5277 (PRE!)

Description as for the genus.

Specimens seen

CAPE: 3219; -DD, between Beukesfontein and De Vloeren, September 1921, fl., Marloth 10530 (PRE); Beukesfontein, 1 June 1973, fr., Glen 690 (BOL)

3319; -BC, Karoopoort, 1 October 1932, fl., Lewis s.n. in NBG 2542/32 (BOL); Ceres District, no date, fl., Trollip s.n. in NBG 3104/15 (BOL); Karoopoort, October 1929, fl., Compton s.n. in NBG 593/29 (BOL); Spes Bona, October 1932, fl., Nielson s.n. in BOL 20494 (BOL); Karoopoort, September 1913, fl., Marloth 5277 (PRE, holotype)

Spirit material: 3319 BC, Ceres Karoo, 11 October 1929, nf., Compton s.n. (BOL)

D. lapidiformis is the only member of the Gibbaeinae which has lateral inflorescences produced two at a time (one on each side of the leaf pair). The bracts are relatively large and fleshy, like miniature leaves, and are conspicuous on most specimens, and in the field for most of the year. In the field, it is one of the two species most difficult to see in its surroundings, as it resembles the pebbles that are common in the area. It is the only species of the Gibbaeinae that grows on black ironstone ridges.

The specimen, Marloth 5277, bears a label in Marloth's handwriting, indicating that it was collected by Alston and is the type. It consists of flowers and whole plants.

6.4 M U I R I A

Muiria N.E. Br., Gard. Chron. 81:116 (1927); Tischer, Monatsschr. D. Kakt. Gess. 1:233 (1929); N.E. Br., Tisch., Karsten, Mesembryanthema :98, 272 (1931); Von Poellnitz, Feddes Rep. 32:55 (1933); Pax & Hoffmann, Natürl. Pflanzenfam. ed. 2 16c:217 (1934); Jacobsen, Succ. Pl. :220 (1935); Goossens, Blompl. :147 (1940); Phillips, Gen. S. Afr. Fl. Pl. ed. 2 :309 (1951); Jacobsen, Handb. Sukk. Pfl. 3:1561 (1955); Schw., Fl. Stones :172 (1957); Jacobsen, Handb. Succ. Pl. 3:1302 (1960); Jacobsen, Sukk. Lex. :471 (1970); Herre, Gen. Mesemb. :220 (1971)

Dwarf succulents composed of one or a few ovoid bodies; bodies each composed of a pair of opposite, completely connate leaves, fissure absent except under cultivation with too much water or not enough light, when a very short fissure develops; bodies ovoid, 22 - 30 - 43 mm long and 12 - 18 - 29 mm in diameter, white in the field, adhering remnants of old growth white to pale buff, new growths white to grass green in cultivation, densely woolly; indumentum of long, straight hairs with undulate walls, arising from all epidermal cells except the guard cells and subsidiary cells of the stomata; epidermal cells uniform in size, four to six-sided, 82,5 - 95 microns in diameter, walls straight to distinctly bowed, outer wall sometimes sculptured with fine dots; stomatal ratio 19%, stomatal aperture 18,5 microns long,

Specimens seen

CAPE: 3320; -DD, 9 miles from Warmwaterberg, no date, nf., Admiraal 242 (PRE)

3321; -CC, Springfontein, June 1932, fr., L. Bolus s.n. in BOL 20121 (BOL); Springfield, no date, fl., fr., Muir 3885 (K, holotype); Springfontein, 19 May 1973, fr., Glen 641 (BOL)

3421; -AD, Still Bay, January 1931, fl., L. Bolus s.n. in BOL 19861 (BOL, K)

Without precise locality: Riversdale division, no date, n.f., Compton and Lamb s.n. in NBG 2302/27 (BOL); Little Karoo, May 1944, fl., fr., Minnaar s.n. (BOL); Little Karoo, no date, nf., Marloth 13734 (PRE)

It is known (O'Connor-Fenton, pers. comm.) that Mrs. Bolus spent a holiday with a friend at Still Bay in January 1931. The Kew duplicate of L. Bol. 19861 has the Still Bay locality deleted and a Springfontein locality inserted in Mrs. Bolus' handwriting. It seems most likely, therefore, in view of the known restricted distribution of this species, that the BOL material is incorrectly labelled.

The leaves of Muiria are connate to the apices, without a fissure, although some large specimens examined in the field had a shallow linear depression where one would expect a fissure. This was seen at the locality of X-Muiriogibbaeummuirioides, which is known to be fertile, so the possibility that this was, in fact, due to the combined effects of the good rains and introgression cannot be discounted.

Muiria is retained as a separate genus because several BOLAID runs with different restraints show that it has little similarity to the genus Gibbaeum. It appears that the main differences are in the completely connate leaves, long simple hairs, large epidermal cels, seeds and polien.

This is the genus that is most likely to suffer extinction by the activity of man, of all the Gibbaeinae. Plants are rare and restricted to a small area at Springfontein. They grow among white quartz, and flower in December.

The type sheet contains nine whole plants, one cut open to show the developing flower and new growth, three capsules and a label in N.E. Brown's handwriting. The capsules contain a flowering plant, a fruiting plant and a rooted plant. The label includes the words "Type specimen !", also in N.E. Brown's handwriting.

6.5 PUTATIVE HYBRIDS

Two hybrids involving the Gibbaeinae, both intergeneric, one natural and one artificial, are known. They are noted briefly below.

6.5.1 X Muiriogibbaeum Jacobsen, Sukk. Pfl. :164 (1933); Jacobsen, Succ. Pl. :221 (1935); Hall, Cact. Succ. Jl. Gt. Brit. 18(2):36, 41 (1956); Rowley, Nat. Cact. Succ. Jl. 11(3) :60 (1958); Jacobsen, Handb. Succ. Pl. 3: 1302 (1960); Jacobsen, Sukk. Lex. :471 (1970)

Putative parentage: Muiria X Gibbaeum

Plant a small succulent. Leaves opposite, connate at the base; fissure extending the full width of the body; body the same shape as M. hortenseae but glaucous. Indumentum patchy, in parts similar to that of G. album, otherwise similar to that of M. hortenseae.

Flowers purple, pink or white, fertile.

Only one putative hybrid species is known in this genus.

X Muiriogibbaeum muirioides Rowley, Nat. Cact. Succ. Jl. 11(3):60 (1958); Jacobsen, Handb. Succ. Pl. 3:1302 (1960); Jacobsen, Sukk. Lex. :471 (1970)

X M. spec. Jacobsen, Sukk. Pfl. :164 (1933); Jacobsen, Succ. Pl. :221 (1935)

G. X muirioides Herre MS, fide Rowley, Nat. Cact. Succ. Jl. 11(3); 60 (1958); Jacobsen, Handb. Succ. Pl. 3:1302 (1960)

Putative parentage: Muiria hortenseae X Gibbaeum album

Iconotype: photograph, in Jacobsen, Sukk. Pfl. :163 (1933)

Description as for the genus.

Specimen seen

Garden material: Kiel, Haas 83 (live plant).

M. hortenseae and G. album grow together in at least one locality. At this locality, many plants of both species, appearing to show introgression with the other, are found. Intermediates, that is, plants showing roughly equal numbers of characters of both species, are present but very rare. A flourishing colony of F2 plants at Kirstenbosch indicates that this hybrid is fertile, as do the many plants of both parental species showing apparent introgression in the field.

No type specimen appears to have been cited by any of the authors who have dealt with this species. However, a photograph of a live specimen available to Jacobsen, who first described the genus, has been published. In terms of Art. 7 of the International Code of Botanical Nomenclature, "a lectotype always takes precedence over a neotype ... a lectotype is a specimen or other element...". In the absence of a specimen the original material, the photograph referred to above is proposed as the lectotype of the hybrid.

6.5.2 X Gibbaeophyllum Glen, gen. hybr. nov.
Genus hybridus novus, e plantis hybridis inter Gibbaeum et Glottiphyllum compositus.

X Gibbaeophyllum coccineum Glen, hybr. nov.

Gibbaeum pubescens subsp. pubescens x Glottiphyllum sp.

Holotype: Karoo Botanical Garden, September 1974, nf., Glen 799 (BOL!)

Planta succulenta, maior quam plurimi Gibbaeinarum; folia opposita, semiteretia, lorata vel digitiformia, basin connata, viridia vel luteoviridia, pubescentia; ambo paris circiter aequaliter magna. Flores ca. 3 - 4 cm diametro; staminodia petaloidea coccinea. Capsulae abortivae.

A relatively large succulent; leaves semi-terete, lorate or digitiform, connate at the base, green or yellow-green, pubescent to minutely pubescent; both leaves of a pair the same size. Flowers ca. 3 - 4 cm in diameter; petaloid staminodes scarlet. Capsule abortive.

This hybrid is said (Bayer, pers. comm.) to have been made in a garden in England. All plants in South Africa were propagated vegetatively from a cutting from this plant. The ease of reproduction by this means is indicated by the large colony at the Karoo Garden, Worcester. According to Stayner (pers. comm.) the plant has been cultivated at Worcester for manyyears, but has never set seed. The only capsule seen by the author was abortive.

It is thought that the parents of this hybrid are probably Gibbaeum pubescens subsp. pubescens and

one of the species of Glottiphyllum commonly grown in European gardens, either Gl. fragrans, Gl. longum or Gl. linguiforme. The leaves of this plant vary in form, some being similar to those of a typical Glottiphyllum, others being similar in shape and vestiture to G. pubescens, but green in colour, and most of them being intermediate in form. The scarlet colour of the petals in this hybrid is explained in section 7.1, as being the result of the production of betacyanins as in Gibbaeum and betaxanthins as in Glottiphyllum. It would appear that the sterility of this hybrid is due to the distant relationship between the parents, as the diploid chromosome number is the same in the putative parental species.

6.6 NOMEN REJICIENDUM

Gibbaeum digitiforme (Thunb.) N.E. Br., ex Nel, Gibbaeum Handb. :112 (1953); Jacobsen, Handb. Succ. Pl. 3:1092 (1960)

Mesembryanthemum digitiforme Thunb., Nov. Act. Nat. Cur. 8:App.6 (1791)

M. digitatum Soland. in Ait., Hort. Kew. ed. 1, 2:181 (1789); Haw., Obs. Gen. Mesemb. 2:139 (1795)

The correct name of this species is Dactylopsis digitata (Soland.) N.E. Br., Gard. Chron. 83:339 (1928). It differs from Gibbaeum in having five-locular capsules and axile placentation, and is therefore placed in the subfamily Mesembryanthemoideae, not in the subfamily Ruschioideae, to which Gibbaeum is assigned.

7. POSSIBLE PHYLOGENY IN THE GIBBAEINAE

Recent theory (Buxbaum, 1948 and others) has it that the Mesembryanthemaceae and Cactaceae are descended from a common Caryophyllalean ancestor. The divergence is said to be a response to the separation of Africa and South America due to continental drift, some 65-million years ago; the Mesembryanthemaceae being chiefly African and the Cactaceae chiefly South American.

Andrews (1961) gives a table allowing one to determine the approximate age of named formations. Comparing this with a geological map of the Little Karoo, one finds that all rocks on which Gibbaeinae are found, were formed long before the Mesembryanthemaceae probably began to evolve as a separate family.

Any cladogram drawn up in this group must therefore be entirely hypothetical.

A cladogram (fig. 11) showing certain morphological trends was drawn up using the following principles:-

1. Species with similar general features, belong together.

2. Major modifications such as the gain or loss of hair, happen rarely and should be minimised in the cladogram.

3. Although reduction in ploidy is possible, it is much less likely than increase in ploidy (Solbrig, 1970).

4. Loss of biochemical pathways (taken in this case to be those leading to the production of flower pigments) is more likely than the reverse.

In this cladogram it is seen that, in general, larger plants are found at the base of the "tree" and smaller ones at the top. This agrees

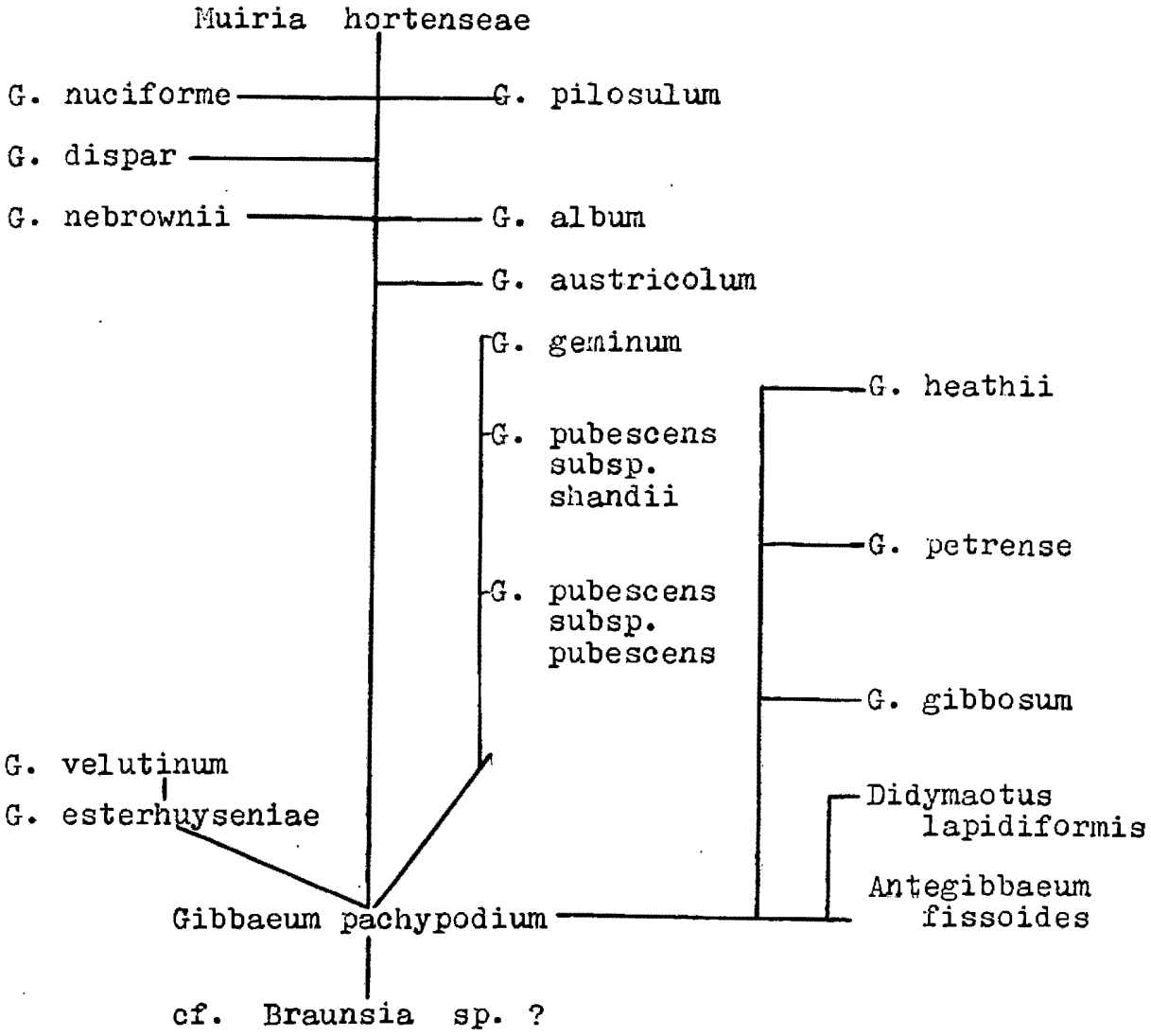


Fig. 11: Cladogram showing suggested relationships between members of the Gibbaeinae.

with the theory held by the Hamburg school (Rappa and Camarrone, 1953; Ihlenfeldt, 1960; 1971) that the evolution of leaf shape in the Mesembryanthemaceae usually proceeds along the series flat - triquetrous - digitiform - hemi-spherical.

The ability to produce coloured betacyanins in the petaloid staminodes is lost five times in the "tree", but if white-flowered species are grouped together then a number of changes must be made, yielding a much less parsimonious tree (cf. Camin and Sokal, 1965; Sneath and Sokal, 1973).

In this "tree" the loss of epidermal hair occurs twice. The reason for placing G. nuciforme as the only hairless member of an otherwise hairy group is that in virtually all other characters, it is very like G. pilosulum, and to place it far away (with the hairless group, above G. heathii) would be to invoke parallel evolution on a grand scale, and again to de-optimise the parsimony of the cladogram.

It will be noted that bracts are gained in one place in the cladogram. While this is not an impossible event, it is an unlikely one, and the possibility that the group is diphyletic, with Didymaotus and Antegibbaeum arising from a different stock to the rest of the group, is not excluded. In that case, the subtribe would be seen as a stage or set of stages on a group of evolutionary lines, rather than as a single line; that is as an "horizontal" rather than a "vertical" taxon (on a cladogram).

Although it is possible to postulate a reduction in ploidy at one or two places in the "tree", it is nowhere necessary to do this.

Characters were scored for relative advancement in the different taxa according to the method of Camin

and Sokal (1965), in order to find the most "primitive" member of the group. It was found that G. pachypodium appeared to have diverged least from the hypothetical ancestral type.

One is now in a position to state some of the characters of a possible ancestor to the Gibbaeinae, and to search for a modern genus to which such a plant might have belonged.

1. The plant may be shrubby or form mats, but it will not be a highly succulent dwarf.

2. The leaves are triquetrous and hairy. On the basis of the size of the leaves of G. pachypodium one might expect the ancestor to have been large for the Mesembryanthemaceae. That this need not necessarily be the case is demonstrated by some very large-leafed populations of G. velutinum, however.

3. The petaloid staminodes are magenta, purple or pink, not yellow, orange, scarlet or white.

4. The ancestor may well have produced echinate seeds. (Haas (pers. comm.)).

5. The capsule is likely to have six locules, but five, the most frequent number in the family, is also likely.

It is found that the only genus that contains plants that fit this description is Braunsia, in the subtribe Lampranthinae. Curiously, Braunsia has echinate seeds and is found virtually throughout the range of the Gibbaeinae. It seems, then, that the Gibbaeinae and Braunsia had a common ancestor, which probably resembled

a species of the latter, more recently than the divergence of the former from any other member of the family.

Haas (pers. comm.) agrees that the ancestor of the Gibbaeinae is to be sought among the Lampranthinae, and is probably Braunsia. His argument is based on capsule morphology.

7.1 Evolution and the biosynthesis of flower pigments

From a variety of observations, mostly in the field, one can deduce the approximate form of the pathway of biosynthesis of the betacyanin pigments in the petaloid staminodes of the Gibbaeinae. It is not necessary to postulate more than one, or at the most two, such pigments in this group.

From the cladogram it is seen that intensely coloured flowers are mostly associated with the more primitive members of the group, and white ones with the more advanced members.

At least some individuals of X Muiriogibbaeum muirioides have purple flowers (Joubert, pers. comm.); Rawe (pers. comm.), however, disagrees; his specimens have white to pink flowers. One parent of the hybrid (Muiria) has only white flowers, while occasional pink flowers, but no purple ones, are reported for the other (G. album).

Occasional pale pink-flowered specimens are found in otherwise white-flowered colonies of G. heathii. A magenta-flowered strain of this species is also known.

The garden hybrid X Gibbaeophyllum coccineum has scarlet flowers, while its presumed ancestors have yellow (Glottiphyllum) and magenta (Gibbaeum) flowers. This enables us to incorporate betaxanthins into the proposed skeleton pathway.

In small-scale evolution, it appears that mutations more often disable an existing pathway than they make new ones available; one change in the active site of an enzyme can inactivate it and so inactivate the whole pathway, but to start a new pathway either a whole new system must be created de novo or else there must be wholesale modification of pre-existing proteins. With this in mind, the following skeleton pathway is built up, using the least number of steps consistent with the available information.

The existence of white-flowered individuals indicates that a colourless precursor is converted by at least one enzyme-catalysed reaction to a magenta pigment (a betacyanin).

The existence of individuals with pale pink flowers in an otherwise white-flowered population, together with the observation of Muir (Nel 1953) and others that in some species, the flowers are white when they first open, but become pink as they wither, indicates that at least one reaction can proceed slowly to a limited extent without enzyme catalysis, or at most with the aid of a severely de-activated one.

The colour of the flower in purple X Muiriogibbaeum is most easily explained by hypothesising

two reactions between precursor and product, the first giving rise to a colourless intermediate. In each ancestor, a different reaction is blocked; in the hybrid, active forms of both enzymes can be and are synthesised, by use of the gene from the appropriate parent.

By the same logic, one can explain why X Gibbaeophyllum should have scarlet flowers. The relevant gene system from Glottiphyllum allows the synthesis of betacyanin(s). The addition of a weak yellow filter to a magenta pigment results in the petaloid staminodes appearing scarlet.

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10. I N D E X

The names of species upheld in this work are in **bold type**. Synonyms are in *italics*. Page numbers in bold type refer to descriptions; those in italics to distribution maps.

This index was produced with the aid of a SNOBOL4 program, INDEX, written by Dr. John M. Chambers, University of Wisconsin. Documentation for this program is contained in a computer file associated with the program file.

13.1 BOLIR Data Base

```
@DATA;L  IREAT
DATABASE-REL.DSK      T:/I-.:.:.:.: 7
0000001       .E.C.I.  I.R.A.I.T.I.O.N
0000002       PAR.E.T  /M.I.  N.M.  ..Y.  I.N.I.M.L.A.E
0000003       TAX...
0000004       .B  .  /.1  .C  .  1                    L.L..A.L.
0000005       .A..    .  .'.  .                 .1..3.E
0000006       .A..    .  .'.  .                    ..1..7
0000007       .A.B    .  .7.  .  .2..1.7      .1.1.27
0000008       CALL    .  .9  .  2.1.2..       ..1.52
0000009       .A..    .  .9  .                 ..1.2..
0000010       CALL    .  .17  .                ..1.1.5.
0000011       .A.D    .  .1.1.0  .5..4.5  -4.1..1.4.
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0000013       CA..    .  ..1.1.  .  .3         ..1.27
0000014       CA..    .14  ..1.1.  ..1.5  ...1..1.2.
0000015       CA..    .1  .1.1.0  .1.7    1...2.0
0000016       TAX...
0000017       .B  .  /.1  .0  .  .  .          .1..A..
0000018       CA..    .1  .1.1  .  1./.0    1...2..
0000019       .A..    .  .1.1  .  .1.1.  1  .1.1.
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0000021       CA..    .  .1.1  .              1  .1.1.
0000022       CA..    .1.  1.1.1.0  .1.1.    .1  .1  1.1.F
0000023       TAX...
0000024       .0  1  /.1.  .0  .  .  .          .1..A..
0000025       C.LA    .1.  .7.  .  .3.4.3.3    1...5.0
0000026       .B..    .  .7.  .  .1.1.1.1.  .  ...1..
0000027       .1..    .  .7.  .              .1.3.0
0000028       .B..    .  .7.  .           .1  .1.5.0
0000029       C.LA    .  .7.  .           .7  .1.0.0
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0000037       C.C.    .  .3.4  .
0000038       C.L.    .  .7.4  .             1.1.5.2
0000039       .C.D    .  .7.5  .    .7.3.    1...3.0
0000040       C.L.    .  .7.6  .             5.1.0.0
0000041       .C..    .  .7.7  .       .3  .4.1..3.0
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0000047       .0  .  /.1.  .0  .  .  .          .1..A..
0000048       C.L.Y   .1  .1.  .    .5.
0000049       .L..    .0  ...3.  .              .  ....
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0000051       C.RY    .  /.1.1.  .       /.  .1.1.1./.
0000052       .L..    .  /.1.1.  .       /.  ..1.1.1./.
0000053       C.L.    .  /.1.1.  .       .3  .  .1.1./.
0000054       C.L.    .  /.1.1.  .    .7.1    7..1.7./.
0000055       I.....
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0000057      0041     1    016 1                  01041
0000058      0043     2    078 4  2324D0          02330
0000059      0045     3    078 1      42
0000060      0047     4    117 4  15D343  7 71301
0000061      0051     5   71316   2136.   2 7197.
0000062      0053    61  13120   2737    12D320 12C F
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0000064      0013     8   73042      030  .0001978
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0000068      0241     2    073 2   2002)     01352
0000069      0251     3    066 2   11428     01940
0000070      0241     4    24 2             20190)
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0000072      28 1   731   26 2   7       2          C1001A
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0000074      TAX0.
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0000081      0212     6   070 1     120   2 02900
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0000085      0222    10   7101 1     701   72.1970
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0000089      0HEA     2   250 1       32    1001920
0000090      0HEA     3   073 1      111  1.11932
0000091      0HEA     4   072 1      106  21 01951
0000092      0HEA     5   012 4 17.332   201 1932
0000093      0HEA     6     2 4 2431231  2011.934
0000094      0HEA     7   072 1       701.) 7.350
0000095      0HEA     8   000 1             41000
0000096      0HEA     9    03 4   22032     21932
0000097      0HEA    10   005 4 2100127    1019200
0000098      0HEA    11   003 1          3 31930
0000099      0HEA    12   201 1     0410    1010920
0000100      0HEA    13    43 4   2.232   1011.332
0000101      0HEA    14   003 2   70 003   201 1950
0000102      0HEA    15  2401.3    2717  11 3.303
0000103      0HEA    16  2.111    2777  2011111.1
0000104      0HEA    17  13120     0413     7.930
0000105      0HEA    18  01230              .0.1
0000106      0HEA    19  1.110     0003     7 320
0000107      0HEA    20  21410     0002     4.1521
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0000109      0HEA    22  21210     0005     01920
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0000111      0HEA    24  00320      197   11.1940
0000112      0HEA    25  71.0203012.014     21950
```

```
CHLA   20  3162.0      521  2222.300          33
CHLA   27  7131.      367  .7722.72          ..
CHLA   20  7103.      733  71 1070           33
CHLA   22  7131.      704  72....            ..
CHLA   21  7101.      705  7212.70           33
CHLA   23  7161.      707  7212.70           33
TAXON
20 1  751  20 .  51    .  1  .  CIL.AEUM
CHAA    1  034 .                1.1332
CHAA    2  241 4  7.551 .241.2250          34
CHAA    3  241 .          .3 .2355          33
CHAA    4  525 . .75402      .191.           33
CHAA    5  241 .  11153  42 .2333           33
CHAA    6  241 4          .3 .2551
TAXON
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CHAA   11  525 . .75402 241 .302            33
CHAA   22  523 . .7240.  . ..4.              ..
TAXON
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CHEA   11  073 2  20311 20 3.332
TAXON
20 1  751  20 .  9     4     .  CIL.AEUM
CHEA 101  073 .     13                      33
TAXON
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CHEE   11  24 4  77132     .1932.           33
TAXON
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CHEE   2  672 4  93657 .1 .1932.            ..
TAXON
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CLCC   11  073 4 1.0331 .01.1332            33
CLCC   .  1.. 4 .75.32 .. 31932.            ..
CLCC   3  675 4 3107.2  71.1932.            33
CLCC   4  .30 .          .2101044           ..
CLCC   5  21410    .320    4.320            33
TAXON
20 1  751  20 . 12      4          CI3.AEUM
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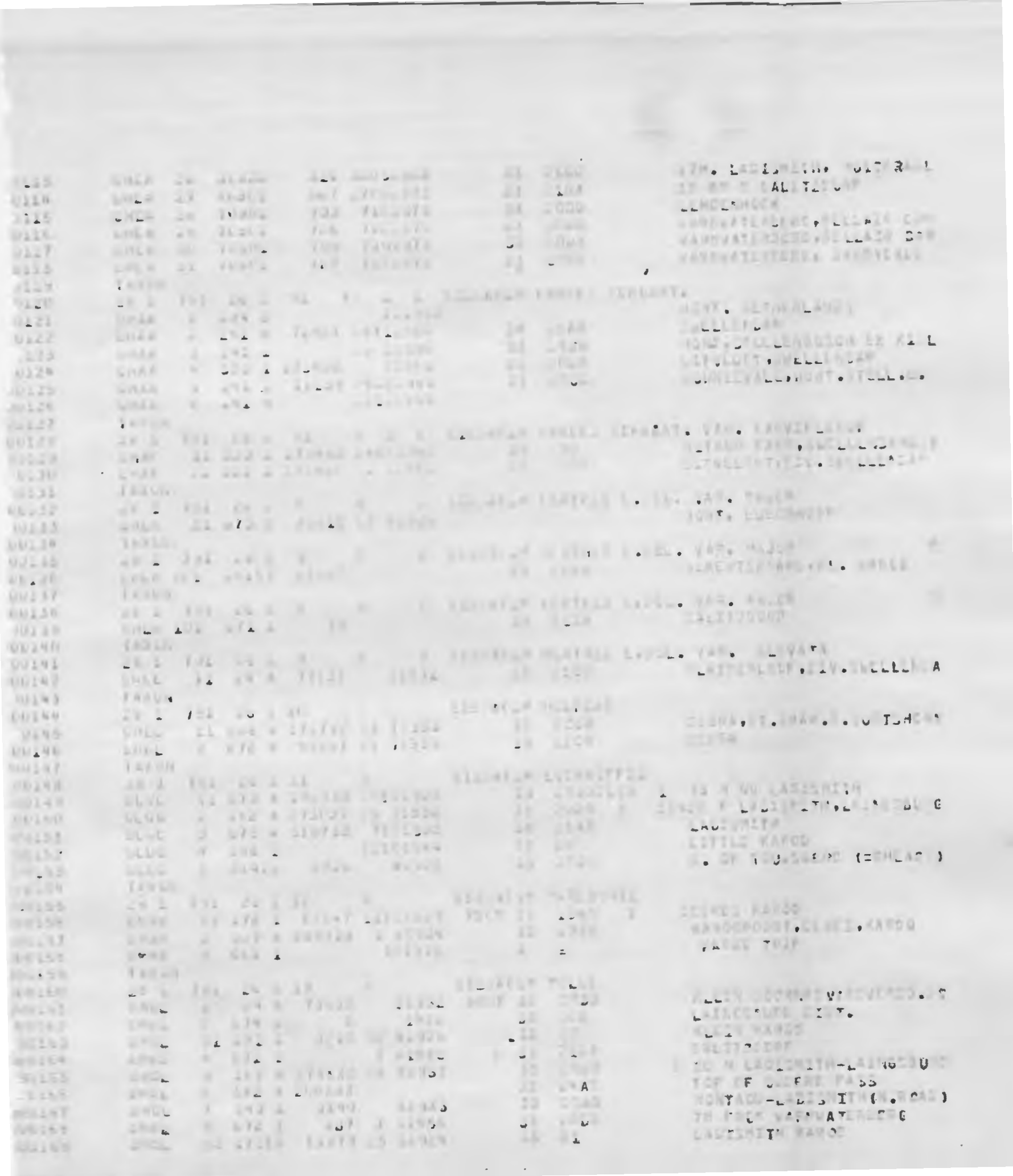
CHAA   2  3.7 4 2544133  3 31.34            33
CHAA   3  611 .           1.1332.           3
TAXON
20 1  751  20 . 13      4          CIL.AEUM
CHCC   .  24 4  7..32      .1.32   33 F 33
CHCC   .  674 .       3     1932.           33
CHCC   31 191 .    3213  .. 4.320          .33
CHCC   4  07. .           3 .1932.      1  32
CHCC   3  102 4 .731.2 .3 31932            33
CHCC   6  102 4 2.0233                     32
CHCC   7  243 .    3140     41933          33
CHCC   8  072 1     107  1 .1955           33
CHCC   32 17216  11479 25 31324            33
```

13.1 BOLIR Data Bank



MOLAIC SYSTEM FOR NUMERICAL AIDS FOR CLASSIFICATION.

OPERATING ON DATA FOR ... GLOSSALOM DATA FOR GENUS REVISION, SERIES 7
OBTAINED BY ..... M.F.CLEA, 10 JUNE 1974

DATA LISTING

101 PER CENT SPACE CONSERVATION
38 ITEMS
94 EQUAL PROPERTIES
0 BINARY PROPERTIES
0 MULTISTATE PROPERTIES
19 EXTRA-VALUE PROPERTIES

PROPERTY	3	2
PROPERTY	4	2
PROPERTY	16	2
PROPERTY	17	3
PROPERTY	18	3
PROPERTY	21	2
PROPERTY	23	2
PROPERTY	24	2
PROPERTY	25	2
PROPERTY	28	3
PROPERTY	29	3
PROPERTY	30	3
PROPERTY	36	3
PROPERTY	39	3
PROPERTY	49	3
PROPERTY	65	3
PROPERTY	83	3
PROPERTY	84	3
PROPERTY	91	3

37 RELATED PROPERTIES

PROPERTY	5	33
PROPERTY	6	33
PROPERTY	7	34
PROPERTY	17	50
PROPERTY	18	50
PROPERTY	27	50
PROPERTY	30	50
PROPERTY	31	50
PROPERTY	32	50
PROPERTY	33	50
PROPERTY	34	50
PROPERTY	37	50
PROPERTY	38	50
PROPERTY	39	50
PROPERTY	40	25
PROPERTY	41	25
PROPERTY	44	50
PROPERTY	45	50
PROPERTY	46	50
PROPERTY	51	25
PROPERTY	52	25

LISTING OF DATA FOR SAVE-MASSED CHAR DECK.

	1	2	3	4	5	6	7	8	9	10	11	12
	13	14	15	16	17	18	19	20	21	22	23	24
	25	26	27	28	29	30	31	32	33	34	35	36
	37	38										
1	0	0	0	0	0	0	0	0	0	0	6	6
	6	6	6	6	6	6	6	6	6	6	6	6
	6	6	6	6	6	6	6	6	6	6	6	6
	6	6										
2	77	58	35	6	30	27	28	81	95	10	89	127
	42	43	26	7	34	85	190	90	74	63	130	64
	30	31	28	17	71	29	156	74	52	70	100	99
	-999	-999										
3.1	500	311	208	84	388	371	630	870	577	366	225	274
	450	432	418	230	403	643	724	721	542	284	368	391
	471	371	264	241	219	372	634	543	347	532	649	-999
	-999	-999										
	536	328	145	120	532	513	602	97	716	437	509	459
	504	434	216	24	713	747	153	417	538	418	656	537
	476	314	268	247	301	347	776	674	454	749	710	-999
	-999	-999										
4.1	-510	-505	218	-451	-515	-505	-459	-999	-999	-999	-999	500
	-522	-522	147	-441	480	-538	-999	-999	-999	-999	709	-999	
	-545	158	-91	81	365	-507	-999	-999	687	-999	-999	-999	
	-999	-999										
	-525	-535	218	-390	-591	-559	-999	-999	-999	-999	-999	663
	-532	-943	104	-930	391	-980	-999	-999	-999	-999	789	-999
	-572	592	-63	7	471	-999	-999	-999	714	-999	-999	-999
	-999	-999										
5	147	175	118	20	134	175	165	199	191	149	110	181
	139	139	118	44	132	140	115	146	170	80	130	145
	140	140	126	10	113	103	178	15	122	134	112	110
	-999	-999										
6	232	217	62	21	224	304	106	279	340	284	206	284
	243	279	146	27	215	261	747	280	318	197	267	255
	203	204	131	24	221	284	189	278	226	254	204	177
	-999	-999										
7	81	79	70	31	88	112	96	110	86	106	46	73
	46	45	37	51	51	80	80	79	80	40	78	54
	74	56	54	51	52	71	62	44	62	55	49	55
	-999	-999										
8	1	1	1	1	1	1	1	1	1	0	0	1

	1	1	1	1	1	1	1	1	1	0	0	0
	0	1	0	1	0	0	1	0	1	1	0	0
	1	1										
9	2	2	2	2	1	2	2	2	3	0	2	2
	0	2	3	2	2	3	2	2	2	2	3	2
	2	2	2	2	2	2	2	2	2	2	2	2
	2	2										
10	40	40	20	40	0	40	40	40	40	0	0	30
	0	0	0	0	20	30	40	40	40	0	0	0
	0	40	0	0	0	0	40	0	40	30	0	0
	30	30										
11	10	20	5	0	10	0	10	5	10	0	30	5
	0	5	10	10	10	5	5	0	5	5	10	0
	0	10	0	0	5	5	0	0	10	5	0	7
	15	15										
12	0	10	20	0	20	30	10	10	30	0	0	5
	0	0	20	0	20	15	5	20	20	5	20	10
	10	10	5	0	5	5	10	15	10	10	15	5
	-99	-99										
13	10	40	10	40	0	40	10	20	30	0	0	20
	0	0	0	0	10	20	10	40	40	0	0	0
	0	10	0	0	0	0	20	0	10	10	0	0
	20	40										
14	0	10	0	40	0	30	0	20	30	0	0	10
	0	0	0	0	0	40	0	30	30	0	0	0
	0	0	0	40	0	0	40	0	0	0	0	-999
	30	30										
15	10	20	10	0	-999	0	10	0	0	-999	-999	0
	-999	-999	-999	-999	0	0	0	0	0	-999	-999	-999
	-999	10	-999	0	-999	-999	10	-999	0	0	-999	-999
	0	0										
16.1	18	18	18	36	18	36	18	18	36	18	18	36
	18	18	18	-999	18	36	-999	-999	-999	18	18	18
	18	-999	36	36	18	18	18	-999	-999	18	-999	18
	36	36										
.2	18	18	36	18	18	54	18	18	36	18	18	36
	18	18	18	-999	18	36	-999	-999	-999	18	18	18
	18	-999	36	36	18	18	18	-999	-999	18	-999	18
	36	36										
17.1	250	110	100	20	90	140	180	120	210	180	150	350
	45	45	200	27	200	390	220	140	250	170	120	250
	250	220	120	36	200	500	127	270	222	127	280	250
	340	200										
.2	250	171	100	33	123	186	269	236	295	217	225	535

	455	3[illegible]										
.3	[illegible]	210	1[illegible]	44[illegible]	191	28[illegible]	400	340	370	300	360	730
	520	[illegible]	[illegible]	5[illegible]	25[illegible]	72[illegible]	430	350	480	260	210	300
	350	[illegible]	[illegible]	700	300	700	211	360	380	190	365	400
	590	570										
10.1	75	150	[illegible]	[illegible]	80	40	80	90	60	100	40	140
	[illegible]	70	[illegible]	[illegible]	150	120	120	[illegible]	90	65	60	200
	[illegible]	127	[illegible]	[illegible]	71	150	108	65	125	127	71	205
	120	130										
.2	112	172	[illegible]	12[illegible]	[illegible]	66	110	103	70	146	62	174
	225	80	148	130	[illegible]	189	179	104	116	76	88	210
	[illegible]	177	70	12[illegible]	64	165	137	70	175	158	84	275
	158	175										
.3	141	220	150	15[illegible]	11[illegible]	90	140	230	100	220	80	240
	[illegible]	90	[illegible]	13[illegible]	[illegible]	260	290	170	140	115	120	220
	[illegible]	221	80	[illegible]	126	180	187	115	205	190	126	400
	[illegible]	270										
19	5	30	40	1[illegible]	4[illegible]	5	3	7	25	5	10	40
	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	40	[illegible]	40	40	15	[illegible]	2
	2	[illegible]	[illegible]	[illegible]	10	2	2	25	2	2	25	7
	40	40										
21.1	[illegible]	[illegible]	[illegible]	[illegible]	45	40	50	22	40	[illegible]	70	[illegible]
	10	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	40	40	10	20	[illegible]
	1	1	[illegible]	[illegible]	10	[illegible]	15	50	[illegible]	15	50	[illegible]
	50	50										
.2	[illegible]	[illegible]	[illegible]	[illegible]	55	[illegible]	50	32	40	10	70	20
	[illegible]	[illegible]	[illegible]	[illegible]	31	[illegible]	[illegible]	[illegible]	60	50	20	5
	[illegible]	[illegible]	[illegible]	[illegible]	50	[illegible]	20	65	15	30	65	15
	[illegible]	[illegible]										
21	10	[illegible]	[illegible]	4[illegible]	21	45	10	40	35	20	50	50
	[illegible]	[illegible]	[illegible]	5	25	45	[illegible]	15	15	50	40	20
	[illegible]	[illegible]	35	[illegible]	50	15	[illegible]	[illegible]	25	[illegible]	40	35
	[illegible]	[illegible]										
22	[illegible]	[illegible]	[illegible]	7	25	[illegible]	45	10	100	8	12	17
	[illegible]	[illegible]	10	1	4	10	4	7	7	9	10	10
	[illegible]	15	15	[illegible]	9	8	4	[illegible]	15	20	9	6
	[illegible]	[illegible]										
23.1	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	26	-999	52	20	55
	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	52	52	35	[illegible]	52
	[illegible]	[illegible]	-999	[illegible]	[illegible]	84	[illegible]	34	[illegible]	[illegible]	34	75
	[illegible]	[illegible]										
.2	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	47	-999	100	50	70
	[illegible]	111	[illegible]		[illegible]	70	[illegible]	71	71	45	[illegible]	100
	[illegible]	[illegible]	-99[illegible]	[illegible]	[illegible]	106	[illegible]	[illegible]	[illegible]	35	[illegible]	125
	[illegible]	[illegible]										

24.1	-999	72	7[illegible]	[illegible]	8[illegible]	3[illegible]	-999	3[illegible]	-999	100	50	125
	49	81	-[illegible]9	[illegible]	2[illegible]	19[illegible]	100	75	75	50	-999	100
	100	-9[illegible]	-99	1[illegible]	6[illegible]	123	18	18	-999	-999	18	120
	116	12[illegible]										
.2	-999	1[illegible]	[illegible]16	12[illegible]	9[illegible]	[illegible]	-999	5[illegible]	-999	120	170	180
	54	117	-[illegible]3	11[illegible]	4[illegible]	25[illegible]	125	95	95	75	-999	120
	120	-999	-[illegible]3	25	174	13[illegible]	30	20	-999	-999	20	140
	150	150										
25.1	-999	72	[illegible]9	[illegible]	3[illegible]	[illegible]	-999	[illegible]	-999	0	0	0
	25	[illegible]	-[illegible]59	[illegible]	[illegible]	[illegible]	40	30	30	25	-999	0
	[illegible]	-99[illegible]	-[illegible]3	[illegible]	14	[illegible]	60	18	-999	-999	18	0
	21	2[illegible]										
.2	-[illegible]9	1[illegible]	[illegible]5	12[illegible]	51	[illegible]	-999	[illegible]	-999	40	0	50
	27	[illegible]	-[illegible]9	[illegible]	13	5[illegible]	50	47	47	30	-999	40
	40	-[illegible]3	-[illegible]9	[illegible]	1[illegible]	[illegible]	70	2[illegible]	-999	-999	20	0
	[illegible]	52										
26	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	7	[illegible]	[illegible]
	7	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	7
	7	[illegible]	-[illegible]9	[illegible]	[illegible]	7	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	[illegible]	[illegible]										
27	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	2	[illegible]
	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	2
	[illegible]	[illegible]										
28.2	[illegible]1	[illegible]0	[illegible]40	1[illegible]	13[illegible]	6[illegible]	100	12[illegible]	9[illegible]	90	150	14[illegible]
	[illegible]0	[illegible]20	[illegible]20	[illegible]0	[illegible]33	14[illegible]	140	110	110	80	120	130
	[illegible]2	[illegible]5	-[illegible]3	[illegible]4	[illegible]0	7[illegible]	115	87	100	63	87	110
	[illegible]00	[illegible]9										
.2	[illegible]2	[illegible]5	[illegible]7	[illegible]1	14[illegible]	[illegible]1	110	15[illegible]	100	129	218	163
	[illegible]0	[illegible]30	[illegible]20	[illegible]3	[illegible]45	[illegible]2	150	132	132	155	120	159
	[illegible]4	[illegible]1	-[illegible]59	[illegible]2	[illegible]43	[illegible]0	132	97	115	75	97	143
	[illegible]4[illegible]	[illegible]13										
.3	[illegible]1	[illegible]0	[illegible]0	[illegible]0	1[illegible]	[illegible]5	120	2[illegible]	120	170	280	210
	[illegible]30	[illegible]4[illegible]	[illegible]20	[illegible]2	16[illegible]	2[illegible]	175	150	150	170	120	190
	[illegible]0	[illegible]27	-[illegible]3	[illegible]2	[illegible]5[illegible]	[illegible]0	149	108	130	87	108	180
	[illegible]30	[illegible]20										
2[illegible].1	[illegible]0	[illegible]4	[illegible]0	[illegible]0	1[illegible]	2[illegible]	10	[illegible]0	20	40	25	35
	[illegible]1	[illegible]0	[illegible]1	[illegible]1	2[illegible]	[illegible]0	35	20	20	15	51	100
	[illegible]0	[illegible]1	-[illegible]97	[illegible]1	[illegible]7	[illegible]2	20	24	52	-999	25	15
	[illegible]0	[illegible]7										
.2	[illegible]2	[illegible]2	[illegible]4	[illegible]4	34	[illegible]4	12	[illegible]0	25	52	49	47
	[illegible]0	[illegible]0	[illegible]2	[illegible]4	[illegible]3	[illegible]6	67	31	31	29	52	110
	[illegible]0	[illegible]2	-[illegible]97	[illegible]5	32	5[illegible]	35	32	52	-999	30	36
	42	[illegible]5										
.4	[illegible]5	[illegible]0	[illegible]0	[illegible]1	45	42	15	100	30	70	65	60
	[illegible]4	[illegible]1	[illegible]3	[illegible]1	60	8[illegible]	90	40	40	40	53	120

	12	5	-9		6		5	4	5	-99	3	6
	6	5										
30.1	2	4	4	4	2	-99	2	-999	-999	0	-999	0
	4	-9	-9				3	3	3	1	-99	0
	0	-9	-9		2	-999	2	2	-999	-999	2	-999
	3	2										
.2	2	5	8		4	-9	2	-999	-999	4	-999	3
	5	-99	-1	3	4	3	6	4	4	3	-99	10
	8	-999	-9	3	3	-9	3	3	-999	-999	3	-999
	5	4										
.3	3	3	14		4	-9	3	-999	-999	7	-999	6
	6	-99	-9	3	6	8	9	5	5	4	-99	12
	8	-99	-9	3	8	-99	4	4	-999	-999	3	-999
	5	7										
31	12	6	9	5	4	2	12	3	7	7	6	13
	9	7	5	11	4	11	8	8	8	3	5	12
	12	4	-9	1	4	6	6	4	4	4	4	6
	8	10										
32	-9	-99	-9	-9	-9	-9	-999	-999	-999	-999	8	-999
	-9	-99	-9	-9	-99	-9	-99	-99	-99	-999	-99	-999
	-99	-99	-9	-9	-9	-9	-999	-999	-999	-999	-999	10
	-99	-9										
33	1	1	1	1	1	1	1	1	1	1	2	1
	1	1	2	2	2	1	1	1	1	1	2	1
	1	1	-1	1	1	1	1	1	1	1	6	1
	1	1										
34	3	4	7	4	2	1	3	2	3	4	4	8
	4	4	-9	3	2	7	4	3	3	2	-99	10
	10	-9	-9	1	2	3	2	2	-999	-999	2	4
	3	4										
35	-9	-9	-9	-9	-99	-9	-99	-99	-999	-999	2	-999
	-9	-99	-9	-9	-999	-9	-999	-999	-999	-999	-999	-999
	-99	-99	-9	-9	-99	-9	-999	-99	-999	-999	-999	8
	-9	-9										
36	4	9	4	3	3	2	4	3	3	4	4	3
	4	3	2	4	2	2	3	2	2	3	2	2
	2	4	3	3	3	4	4	2	4	3	4	2
	3	3										
37	10	3	10	3	10	10	10	10	10	10	10	3
	9	5	3	1	4	10	2	9	9	9	5	9
	9	5	10	1	9	9	8	10	5	4	10	9
	9	9										
38.1	6	3	5	7	9	3	4	1	17	16	15	25
	25	2	10	22	20	20	2	11	17	13	12	25
	3	13	11	25	14	5	12	25	19	12	25	25
	25	1										

							116	199	210	183	200	365
							169	289	272	159	275	312
							290	300	240	290	500	
							211	325	190	300	400	
							40	90	50	60	30	120
							120	50	70	40	50	200
							108	40	125	127	44	205
							102	165	74	134	57	156
							170	88	95	86	81	210
							107	88	175	159	94	275
							130	230	100	220	80	200
							290	120	130	130	120	220
							160	130	205	130	143	400
40							175	80	220	140	198	373
							156	92	92	154	200	119
							113	150	137	136	150	248
41						-999	75	34	40	74	55	52
						76	71	50	50	54	51	77
						60	56	55	26	-999	55	37
42						-999	-999	20	30	50	26	22
						22	32	22	22	-999	-999	54
						20	16	28	-999	-999	28	18
43						13	27	35	25	28	45	41
						27	19	14	15	40	27	30
						20	16	25	27	17	25	42
44						42	70	44	42	64	117	96
						116	63	55	55	66	62	220
						90	44	53	62	63	53	109
						86	46	27	35	39	99	58
						86	38	32	32	42	38	60
						60	25	28	38	41	26	66
46						47	105	38	60	76	68	77

						80	82	61	61	44	45	125
						50	53	41	-999	10	41	64
						17	30	24	25	44	44	52
						76	43	32	32	32	11	90
						34	11	22	-999	-999	23	40
						1	-999	2	2	4	1	3
						3	4	2	2	2	2	4
							3	1	2	-999	1	4
						10	10	30	5	20	14	11
						8	7	5	5	8	70	60
						30	40	20	50	50	22	12
						15	12	57	9	29	33	17
						25	13	9	9	13	70	60
						30	44	27	55	52	22	30
						21	15	60	12	38	60	21
						32	18	17	17	25	70	60
						50	49	24	60	55	22	42
						-350	93	-999	80	250	-999	180
						180	316	72	72	75	240	250
						410	133	75	240	150	75	53
						0	0	0	0	0	0	0
						0	1	0	0	0	0	0
						0	0	0	0	0	0	0
						0	0	0	0	0	0	0
						0	0	0	0	0	0	0
						0	0	0	0	0	0	0
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						0	45	0	0	5	0	0
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						0	0	0	0	0	5	0
						0	45	0	0	90	0	0

56	0	0	0	0	0	0	0	0	0	0	0	0
	1	1	30	0	5	0	0	0	0	0	90	0
	0	0	0	0	0	0	5	0	5	5	0	0
	1	1										
57	0	0	0	0	0	0	0	0	0	0	5	0
	0	0	0	0	45	0	0	0	0	0	5	0
	0	45	0	0	0	0	0	0	45	0	0	0
	0	0										
58	0	0	0	0	0	5	0	90	0	5	45	5
	5	0	0	0	45	5	0	0	0	5	0	0
	0	45	5	0	0	0	0	5	45	0	5	5
	0	0										
59	10	0	0	1	90	50	10	5	0	45	45	45
	90	5	0	0	0	45	0	5	5	90	0	0
	0	0	30	45	30	5	0	90	5	0	90	15
	5	5										
60	30	0	0	0	0	40	90	0	5	45	5	45
	0	0	0	45	0	45	0	90	5	90	0	.5
	90	0	0	45	0	90	0	5	0	0	5	60
	45	45										
61	0	0	0	0	0	5	0	0	90	5	0	5
	0	0	0	45	0	5	40	0	5	0	0	90
	0	0	0	0	0	5	0	0	0	0	0	15
	45	45										
62	0	0	0	0	0	0	0	0	5	0	0	0
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	0	0	0	0	0	0	0	0	0	0	0	5
	5	5										
63	5	5	1	0	6	5	3	5	5	1	1	5
	5	0	5	0	6	1	6	5	5	2	5	1
	1	6	6	0	2	10	1	2	6	6	2	5
	4	4										
64	5	0	3	0	5	1	5	6	8	1	9	5
	5	5	2	0	2	2	2	1	1	5	2	5
	5	5	5	0	5	1	2	5	5	2	5	2
	5	5										
65.1	5717	6[illegible]	[illegible]	[illegible]	[illegible]	575[illegible]	5917	6[illegible]	6270	4370	7220	8500
	4[illegible]	52[illegible]	4[illegible]2	4[illegible]	4333	775[illegible]	4333	6000	6000	5000	4292	5040
	5[illegible]	52[illegible]	[illegible]7	77[illegible]	[illegible]	4[illegible]	5200	5000	5222	4333	5000	5250
	[illegible]	8000										
.2	[illegible]744	6[illegible]	[illegible]	674[illegible]	[illegible]779	6611	6744	6217	7244	5402	12130	9750
	[illegible]33	65[illegible]2	[illegible]55	597[illegible]	[illegible]987	8947	4987	7195	7195	6279	4955	5673
	5673	5[illegible]	6779	894[illegible]	[illegible]277	5402	6292	6278	5900	4987	6277	6231
	[illegible]	8[illegible]										

.3	7283	8041	1863	7251	7316	7117	7283	6570	8870	6170	16890	11560
	6600	7770	5833	7420	5601	9750	5500	8350	8350	7500	5833	6833
	6833	6833	7216	6750	7500	6170	7333	7500	6733	6500	7500	7500
	10250	10250										
66	1542	1740	1176	1554	1534	1404	1542	1512	1788	1274	1311	1358
	1334	1401	1448	1472	1396	1571	1396	1603	1613	1542	1348	1273
	1275	1377	1534	1571	1543	1274	1535	1542	1777	1395	1542	1637
	1650	1650										
67	1457	2207	1739	1457	1686	1315	1497	1748	1932	1329	1520	1747
	1411	1814	1765	1832	1325	1625	1325	1945	1945	1571	1255	1467
	1467	1358	1536	1482	1571	1333	1568	1571	1756	1325	1570	1215
	1650	1650										
68	971	1265	1134	971	1085	917	971	1155	1391	1043	1160	940
	1042	1317	931	1144	997	1125	997	1214	1214	1018	931	1153
	1153	985	1085	1030	1019	1043	1121	1218	985	937	1019	1047
	1101	1101										
69.1	258	280	177	268	257	254	268	370	244	203	-999	275
	303	234	110	139	331	275	331	240	240	250	271	228
	228	277	157	271	250	203	250	250	277	331	250	288
	275	275										
.2	341	324	228	342	374	402	341	394	312	307	-999	339
	345	291	329	312	394	336	394	317	313	332	329	386
	386	341	174	307	332	307	364	333	330	394	332	377
	358	358										
.3	402	372	351	401	465	545	409	480	376	442	-999	392
	350	339	406	371	428	437	529	387	387	462	406	515
	515	472	435	437	462	442	494	462	472	528	462	490
	422	422										
70	30	0	45	20	55	40	50	50	65	15	100	30
	45	30	40	10	30	40	30	12	12	20	40	15
	15	40	35	4	20	15	30	20	40	30	20	20
	41	41										
71	50	45	35	30	35	50	50	50	50	35	-999	50
	35	30	50	20	50	40	30	30	30	20	50	35
	35	40	55	4	20	35	30	20	40	50	20	30
	40	40										
72	135	0	130	29	333	350	235	131	266	345	589	590
	300	320	231	327	261	430	241	476	476	294	231	223
	223	221	322	431	294	345	137	294	221	260	294	198
	481	480										
73	265	135	211	281	396	288	285	100	299	179	-999	395
	268	322	297	251	203	347	303	347	347	227	287	270
	270	252	155	47	227	179	233	227	202	203	227	257
	365	365										
74	217	1	118	217	129	198	217	101	189	190	419	277
	202	217	147	253	169	258	169	210	210	156	148	164

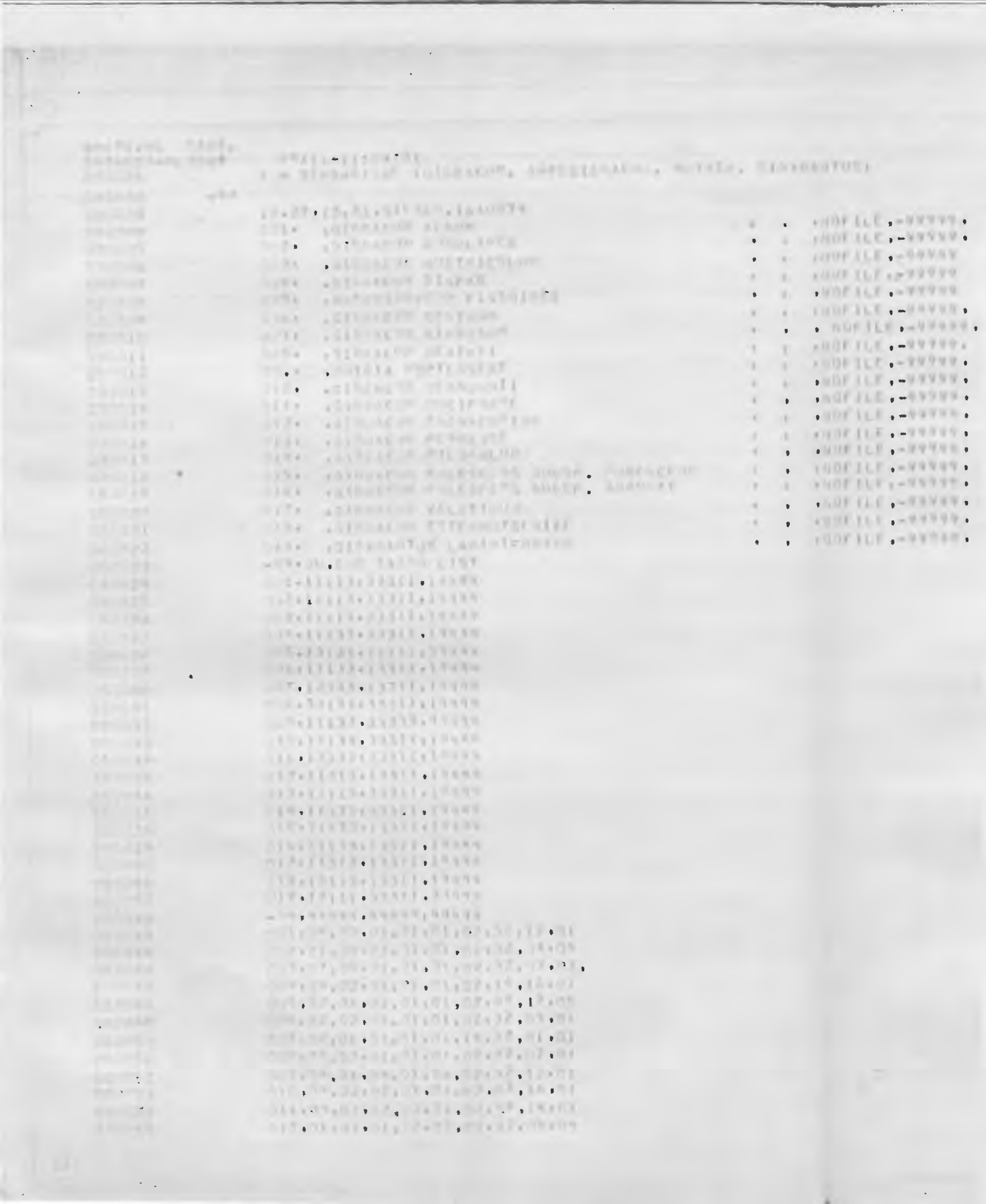
						156	100	104	156	189	160	156
	75			173			113	170	101	196	84	-999
						113	102	113	130	130	120	148
						120	84	121	120	126	113	120
	76					1	20	5	5	5	5	10
							20	2	100	100	55	4
						55	5	20	55	1	2	55
	77						20	55	5	20	60	-999
						70	15	70	75	75	55	82
							10	20	55	58	70	55
	78						48	40	39	138	5	232
						24	72	24	0	0	6	40
							5	124	6	40	24	6
	79					5	5	10	48	29	10	-999
							5	5	0	0	2	2
						2	13	36	2	4	5	2
	80.1					14	17	17	14	16	14	-999
						14	18	-999	14	14	17	14
						17	14	-999	17	14	14	17
	.2					16	18	18	17	19	18	-999
						18	20	-999	17	17	19	18
						19	18	-999	19	18	18	19
	.3						22	22	20	22	23	-999
						23	23	-999	20	20	20	23
						20	23	-999	20	23	23	20
	81.1					12	11	11	11	11	11	-999
						11	15	-999	11	11	12	11
						12	11	-999	12	11	11	12
	.2					14	14	14	14	14	15	-999
						15	18	-999	14	14	16	15
						16	15	-999	16	15	15	16
	.3					15	16	16	17	16	20	-999
						20	20	-999	17	17	18	20
						18	20	-999	18	20	20	18

1

82	3	3	3	[illegible]	3	3	3	3	3	3	3	3
	3	3	3	[illegible]	3	3	3	3	3	3	3	3
	3	3	3	[illegible]	3	3	3	3	3	3	3	3
	3	3										
83	80	90	75	[illegible]	80	80	80	90	80	75	-999	55
	75	75	75	75	75	55	-999	90	90	70	75	75
	75	75	80	[illegible]	70	75	-999	70	75	75	70	15
	55	55										
84	5	3	4	[illegible]	5	5	5	3	4	4	-999	5
	4	4	4	[illegible]	4	5	-999	3	3	4	4	4
	4	4	5	5	4	4	-999	4	4	4	4	4
	5	5										
85	144	264	220	144	269	144	144	264	383	220	-999	44
	220	220	220	220	220	44	-999	264	264	196	220	220
	220	220	289	44	196	220	-999	196	220	220	196	72
	44	44										
86	12	13	13	12	13	12	13	13	12	12	-999	13
	12	13	12	[illegible]	12	13	-999	12	13	12	12	13
	12	13	12	[illegible]	13	12	-999	12	13	12	13	11
	13	[illegible]										
87	65	60	80	[illegible]	90	90	65	80	75	95	40	80
	95	95	90	75	95	90	0	90	90	85	90	95
	95	90	90	[illegible]	85	55	60	85	90	90	85	80
	90	90										
88	110	90	120	[illegible]	105	95	110	97	95	95	110	100
	95	95	120	[illegible]	95	100	0	110	110	100	120	95
	95	95	105	[illegible]	100	95	120	100	95	95	100	95
	110	110										
89	[illegible]	60	60	[illegible]	45	80	65	15	35	75	70	0
	75	75	50	[illegible]	20	0	-999	10	10	5	50	75
	75	60	40	[illegible]	5	75	80	5	20	20	5	60
	10	10										
90	60	10	25	[illegible]	5	10	60	25	30	10	100	10
	15	10	15	[illegible]	40	10	-999	5	5	25	15	10
	10	40	5	[illegible]	25	10	10	25	40	40	25	100
	5	5										
91	15	15	30	[illegible]	25	20	15	15	15	35	45	20
	35	35	20	[illegible]	22	20	-999	25	25	15	20	35
	25	22	25	[illegible]	15	35	20	15	22	22	15	50
	25	25										
92	8	10	12	[illegible]	20	18	8	12	10	18	12	12
	18	18	12	[illegible]	20	12	-999	15	15	12	12	18
	18	20	20	12	12	18	10	12	20	20	12	40
	15	15										
93	30	30	20	[illegible]	30	20	30	20	30	30	45	40
	30	30	30	[illegible]	45	40	-999	30	30	23	30	30

	30	45	30	4	28	37	30	28	45	45	28	75
	30	30										
94	8	20	20	24	15	8	8	8	10	8	20	5
	8	8	8	8	15	5	-999	15	15	8	8	8
	8	15	15	8	8	8	10	8	15	15	8	20
	15	45										

LISTING OF DATA FOR CARD DECK .....
FILE USED FOR STORAGE OF DATA .....
CHECKS MADE AGAINST SOURCE ON .....
CORRECTIONS AS NEEDED ENTERED .....
FINAL CHECKING CARRIED OUT BY .....



Appendix 4: Terminology

Brief definitions of some non-botanical terms, and some terms mostly used in discussions of the Mesembryanthemaceae, are given below.

Binary. A binary character is one that may only assume two states, e.g. present or absent.

Body. When referring to a very reduced succulent plant, the body is normally considered to be a pair of leaves (connate for much of their length) and associated stem or rootstock. This is usually a whole plant.

Centroid. A centroid (between two or more OTU's) is a geometric mean over all property vectors in character hyperspace.

Character suite. A character suite is a set of unit characters such that all of them refer to the same part (e.g. leaves, limbs) or phase (e.g. seed, larva) of the organism.

Covering membrane. Under the valves, the capsules of some members of the Mesembryanthemaceae have a membrane which covers each locule partly or completely. This is referred to by several names, of which the present is the most correct.

File. In computing terminology, a file is a set of data which are stored together in a single area of mass storage (magnetic disc or tape), and which are conventionally used together. Programs may be stored in files for convenience.

Frequency modulation is a method for de-emphasising similarities among low values of modal properties, thus suppressing spurious similarities due to zero-values (Hall, 1970).

Hygroscopic. A capsule which opens when wet and remains open as it dries, is called hygroscopic.

Hygrochastic. A capsule which opens when wet and closes as it dries, so that the process may be repeated is called hygrochastic.

Hyperspace is space in more than three dimensions. In numerical taxonomy, the concept of a graph with as many orthogonal axes as there are characters in the study is often used, and labelled "character hyperspace".

Lophomorphic. A nectary which is raised like a crest is termed lophomorphic.

Modal properties are all those that are continuously variable.

Multistate properties may assume more than two states; they are not continuously variable.

OTU. An operational taxonomic unit (abbreviated OTU) is the smallest taxonomic unit in the study. It may be an individual, population, species, genus or any other rank of taxon.

Placental tubercle. A placental tubercle appears as an outgrowth of the (parietal) placenta, that partially or completely blocks the aperture at the open end of the covering membrane.

Polyclave. A polyclave or multiple-entry key is any identification system in which characters may be selected in any order, one or more at a time, from a predetermined set, to identify an unknown.

Relevance. In numerical taxonomy, relevance is a measure of the number of characters out of a given set that are applicable to the OTU in hand, where the character set involves all characters of a number of arbitrarily chosen suites, as found in all the members of the group that the OTU in hand belongs to.

Set. A set is a number of entities that have some defining character or characters in common.

Subset. A subset is part of a predefined set such that all members of the subset have some character or characters in common.

Valve wings. These are membranous extensions of the expanding keels (ridges of much-thickened tissue, two per valve, that take up water and force the valve open), usually free from the valve, on either side of it.

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BOLAID SYSTEM FOR NUMERICAL AIDS FOR CLASSIFICATION.
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  OPERATING ON DATA FOR ...  LIBRARY DATA FOR GENUS REVISION, SERIES 7
  OBTAINED BY .............  M.F.GLEN, 10 JUNE 1974


    1  GROUP FORMING
  100  PERCENT SPACE CONSERVATION
   33  ITEMS
  100   MODAL PROPERTIES
    0            BINARY PROPERTIES
    0       MULTISTATE PROPERTIES
   19  EXTRA-VALUE PROPERTIES
           PROPERTY     .... 2
           PROPERTY   4 .... 2
           PROPERTY  16 .... 2
           PROPERTY  17 .... 3
           PROPERTY  18 .... 3
           PROPERTY  2  .... 2
           PROPERTY  23 .... 2
           PROPERTY  24 .... 2
           PROPERTY  25 .... 2
           PROPERTY  28 .... 3
           PROPERTY  29 .... 3
           PROPERTY  3  .... 3
           PROPERTY  38 .... 3
           PROPERTY  39 .... 3
           PROPERTY  49 .... 3
           PROPERTY  65 .... 3
           PROPERTY  69 .... 3
           PROPERTY  73 .... 3
           PROPERTY  81 .... 3
   37  WEIGHTED PROPERTIES
           PROPERTY   5 .... 33
           PROPERTY   6 .... 33
           PROPERTY   7 .... 34
           PROPERTY  17 .... 50
           PROPERTY  18 .... 50
           PROPERTY  27 .... 50
           PROPERTY  30 .... 50
           PROPERTY  31 .... 50
           PROPERTY  32 .... 50
           PROPERTY  33 .... 50
           PROPERTY  34 .... 50
           PROPERTY  37 .... 50
           PROPERTY  38 .... 50
           PROPERTY  39 .... 50
           PROPERTY  40 .... 25
           PROPERTY  41 .... 25
           PROPERTY  44 .... 50
           PROPERTY  45 .... 50
           PROPERTY  46 .... 50
           PROPERTY  51 .... 25
           PROPERTY  52 .... 25
```

PROPERTY 51 20
PROPERTY 54 25
PROPERTY 55 25
PROPERTY 56 0
PROPERTY 57 25
PROPERTY 58 0
PROPERTY 59 25
PROPERTY 60 25
PROPERTY 61 25
PROPERTY 62 25
PROPERTY 63 75
PROPERTY 64 75
PROPERTY 65 75
PROPERTY 66 75
PROPERTY 80 50
PROPERTY 81 50
NO FREQUENCY POPULATION
ARBITRARILY POPULATED PROPERTIES
PROPERTY 51 100
PROPERTY 54 100
PROPERTY 55 100
PROPERTY 56 100
PROPERTY 57 100
PROPERTY 58 100
PROPERTY 59 100
PROPERTY 60 100
PROPERTY 61 100
PROPERTY 62 100
PROPERTY 63 100
DATA FOR THE FILE FORMAT
CLOSING FILE DATUM

DATA AND FOR A PASS-THROUGH FILE.

GENERAL FIELD-MOVING SYSTEM.

SIMILARITY MATRICES AND LANGUAGES.

CLUSTERS ARE IDENTIFIED BY THEIR SMALLEST-INDEXED MEMBER.

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	

2 .735

3 .743 .703

4 .802 .741 .736

5	.704	.715	.729	.729															
6	.784	.800	.816	.791	.722														
7	.838	.765	.746	.807	.750	.709													
8	.766	.784	.838	.873	.727	.776	.771												
9	.715	.727	.732	.886	.726	.715	.778	.752											
10	.752	.837	.724	.712	.763	.724	.745	.738	.672										
11	.716	.813	.802	.852	.897	.813	.845	.816	.747	.811									
12	.740	.832	.782	.767	.719	.738	.735	.795	.712	.774	.842								
13	.784	.727	.736	.727	.759	.762	.776	.727	.712	.676	.837	.752							
14	.732	.712	.742	.732	.760	.715	.772	.763	.771	.840	.714	.745	.877						
15	.746	.805	.728	.729	.900	.772	.776	.776	.721	.748	.896	.725	.829	.824					
16	.772	.703	.762	.732	.756	.742	.763	.742	.734	.809	.758	.772	.824	.823	.805				
17	.745	.833	.840	.823	.732	.772	.773	.776	.791	.757	.867	.744	.792	.759	.830	.787			
18	.738	.816	.784	.774	.838	.712	.838	.727	.740	.845	.824	.716	.775	.713	.740	.775	.741		
19	.758	.837	.894	.779	.672	.805	.784	.812	.837	.732	.804	.747	.732	.747	.719	.708	.777	.718	
21	.736	.760	.732	.756	.791	.773	.746	.742	.741	.722	.835	.763	.739	.722	.723	.740	.762	.780	.712
21	.743	.746	.752	.778	.754	.776	.735	.774	.718	.718	.837	.772	.737	.736	.773	.745	.763	.767	.719	.826
22	.736	.818	.743	.813	.725	.748	.736	.785	.732	.714	.817	.771	.814	.807	.805	.837	.769	.737	.698	.757
	.734																			
23	.765	.710	.768	.818	.812	.736	.761	.765	.731	.742	.807	.736	.870	.833	.930	.804	.830	.738	.732	.730
	.730	.802																		
24	.741	.714	.736	.818	.743	.741	.740	.778	.674	.826	.877	.719	.848	.843	.803	.787	.766	.720	.714	.710
	.740	.778	.804																	
25	.742	.698	.729	.732	.746	.716	.796	.772	.814	.822	.867	.703	.841	.838	.798	.779	.757	.714	.717	.710
	.740	.710	.741	.712																
26	.830	.746	.742	.768	.779	.772	.817	.816	.747	.743	.774	.772	.871	.818	.825	.776	.874	.753	.779	.751
	.758	.843	.823	.756	.796															
27	.746	.732	.742	.802	.814	.736	.765	.732	.737	.717	.865	.744	.872	.838	.804	.781	.772	.729	.693	.764
	.742	.806	.802	.778	.760	.778														
28	.716	.832	.742	.757	.804	.714	.736	.716	.719	.845	.850	.732	.775	.716	.733	.727	.734	.899	.722	.751
	.749	.736	.738	.762	.737	.740	.728													
29	.776	.722	.705	.742	.777	.716	.768	.742	.716	.714	.700	.771	.802	.805	.793	.838	.761	.738	.695	.749

	.752	.540	.756	.778	.748	.775	.756	.787											
30	.755	.595	.732	.737	.750	.734	.782	.718	.681	.695	.674	.725	.850	.853	.806	.813	.772	.772	.741	.735
	.724	.784	.697	.624	.620	.706	.762	.704	.790											
31	.773	.740	.638	.758	.607	.771	.774	.801	.771	.732	.644	.721	.720	.718	.756	.729	.743	.742	.720	.721
	.782	.707	.782	.761	.694	.719	.763	.741	.730	.632										
32	.781	.720	.754	.760	.748	.730	.783	.757	.796	.784	.702	.701	.878	.758	.816	.871	.778	.741	.685	.771
	.773	.691	.812	.769	.777	.716	.822	.726	.822	.775	.717									
33	.824	.799	.764	.781	.774	.814	.818	.807	.782	.779	.679	.787	.817	.820	.825	.778	.870	.795	.799	.759
	.782	.768	.624	.792	.770	.805	.782	.761	.717	.727	.766	.741								
34	.804	.724	.764	.732	.767	.736	.802	.749	.796	.761	.696	.777	.808	.813	.823	.778	.838	.754	.795	.763
	.767	.769	.821	.776	.758	.800	.781	.782	.760	.784	.774	.755	.883							
35	.783	.729	.752	.763	.774	.767	.781	.780	.793	.733	.777	.704	.810	.736	.810	.824	.774	.744	.692	.765
	.746	.690	.804	.779	.749	.814	.796	.816	.779	.781	.693	.737	.785	.792						
36	.707	.682	.760	.693	.731	.671	.693	.697	.652	.732	.705	.748	.743	.775	.749	.795	.724	.687	.709	.698
	.636	.760	.747	.723	.735	.714	.714	.698	.758	.746	.670	.748	.730	.738	.747					
37	.764	.724	.778	.812	.742	.764	.780	.752	.771	.706	.687	.737	.735	.738	.749	.750	.766	.837	.736	.822
	.727	.766	.742	.712	.834	.744	.767	.815	.764	.737	.762	.774	.797	.784	.777	.894				
38	.782	.722	.771	.812	.792	.732	.774	.742	.771	.732	.687	.817	.732	.730	.748	.756	.763	.804	.739	.823
	.823	.768	.745	.835	.852	.780	.772	.822	.765	.731	.762	.778	.792	.781	.757	.898	.916			

LINE 1. 32 LINES TO 38 AT PROBABILITY LEVEL .777

LINE 32. 1 LINES TO 7 AT PROBABILITY LEVEL .8307

LINE 1. 32 LINES TO 32 AT PROBABILITY LEVEL .1000

LINE 1. 32 LINES TO 31 AT PROBABILITY LEVEL .0938

LINK 5. 26 LINKS TO 33 AT [illegible] LEVEL .158

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LINK 7. 37 LINKS TO [illegible] AT HOMOGENEITY LEVEL .[illegible]24

LINK [illegible] 2 LINKS TO [illegible] AT HOMOGENEITY LEVEL .311[illegible]

LINK 9. 22 LINKS TO 32 AT HOMOGENEITY LEVEL 1.[illegible]

LEVEL AT F[illegible] 7 [illegible]

LINK [illegible] 1 LINKS TO 2 AT [illegible] HOMOGENEITY LEVEL [illegible]

LINK 11. 17 LINKS TO 34 AT HOMOGENEITY LEVEL .8312

LINK [illegible] [illegible] 5 TO 26 AT HOMOGENEITY LEVEL .85564

LINK 13. 10 LINKS TO 13 AT HOMOGENEITY LEVEL .87943

LINK 14. 5 LINKS TO 27 AT HOMOGENEITY LEVEL .86157

LINK 15. 10 LINKS TO 14 AT HOMOGENEITY LEVEL .85571

LINK 16. 10 LINKS TO 24 AT HOMOGENEITY LEVEL .83532

LINK 17. 18 LINKS TO 37 AT HOMOGENEITY LEVEL .84794

LINK 18. 10 LINKS TO 30 AT HOMOGENEITY LEVEL .84447

LINK 19. 11 LINKS TO 15 AT HOMOGENEITY LEVEL .84164

LINK 20. 12 LINKS TO 28 AT HOMOGENEITY LEVEL .83290

LINK 21. 5 LINKS TO 10 AT HOMOGENEITY LEVEL .82852

LINK 24. S 23973 TO 27 AT HOMOGENEITY LEVEL .02545

HIERARCHICAL OF 4000'S 20 CLUSTERINGS.

	1	2	3	4	5	6	8	9	11	17	18	19	20	27	31	38
2	.743															
3	.742	.635														
4	.752	.733	.746													
5	.738	.742	.747	.730												
6	.763	.615	.718	.735	.751											
8	.747	.720	.662	.713	.757	.774										
9	.754	.723	.723	.743	.732	.715	.731									
11	.636	.517	.653	.647	.692	.672	.651	.641								
17	.763	.720	.752	.735	.773	.732	.743	.739	.609							
18	.715	.712	.752	.727	.715	.738	.736	.725	.700	.716						
19	.745	.687	.672	.723	.730	.642	.711	.690	.532	.714	.707					
20	.735	.716	.737	.736	.752	.715	.753	.726	.601	.681	.748	.722				
27	.756	.732	.751	.732	.619	.723	.745	.719	.717	.732	.325	.698	.795			
31	.744	.712	.672	.713	.727	.706	.735	.716	.637	.726	.722	.702	.704	.703		
38	.677	.654	.646	.646	.784	.646	.671	.652	.646	.687	.763	.701	.695	.744	.665	

LINK 25. 27 CLUSTERS TO 22 AT HOMOGENEITY LEVEL .03486

	1	2	3	4	5	6	8	9	11	17	18	19	20	27	31	38
2	.743															
3	.742	.635														
4	.752	.733	.746													

5	.7[illegible]	.[illegible]	.747	.[illegible]									
6	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.761								
9	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]							
8	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]						
11	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]					
12	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.773	.[illegible]	.[illegible]	.[illegible]	.[illegible]				
15	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]			
16	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.711	.[illegible]	.[illegible]	.[illegible]	.[illegible]		
20	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.722	
21	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.727	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]
25	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.686

[illegible] LEVEL .[illegible]

	1	2	3	4	5	6	8	9	11	12	19	27	31	38
2	.[illegible]													
3	.[illegible]	.711												
4	.[illegible]	.[illegible]	.[illegible]											
5	.[illegible]	.[illegible]	.[illegible]	.[illegible]										
6	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.772									
7	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]								
9	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.757	.[illegible]	.[illegible]							
11	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]						
12	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.773	.[illegible]	.761	.[illegible]	.[illegible]					
15	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]				
20	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.741			
21	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.724	
26	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.[illegible]	.692	.675	

LINK 25. 2 LINKS TO 9 AT HOMOGENEITY LEVEL .05877

	1	2	3	5	6	8	9	11	12	13	27	31	38
4	.784												
5	.720	.714											
7	.802	.750	.776										
8	.782	.833	.712	.772									
9	.732	.744	.650	.776	.715								
10	.760	.740	.720	.757	.740	.702							
11	.684	.622	.660	.726	.611	.649	.691						
12	.769	.725	.752	.779	.760	.712	.758	.649					
29	.746	.629	.664	.765	.699	.716	.695	.653	.714				
30	.711	.773	.779	.781	.812	.772	.773	.624	.672	.741			
32	.764	.717	.692	.761	.767	.715	.767	.646	.740	.779	.729		
39	.636	.669	.703	.766	.774	.684	.662	.737	.617	.776	.692	.675	

LINK 26. 4 LINKS TO 3 AT HOMOGENEITY LEVEL .08187

	1	2	3	6	8	9	11	12	13	25	31	38
2	.736											
3	.761	.703										
4	.734	.664	.714									
8	.773	.740	.687	.772								
9	.768	.736	.724	.760	.732							
11	.723	.622	.662	.670	.657	.694						
12	.783	.722	.736	.768	.759	.716	.682					
19	.716	.671	.678	.691	.720	.634	.610	.721				
20	.772	.718	.776	.802	.759	.752	.672	.680	.733			

31	.750	.715	.691	.765	.790	.766	.641	.741	.706	.722
36	.754	.660	.699	.672	.683	.661	.707	.694	.703	.689	.672

LINK 27. 6 LINKS TO 20 AT HOMOGENEITY LEVEL .80859

	1	2	3	6	8	9	11	12	19	31	36
2	.736										
3	.765	.719									
6	.799	.766	.770								
8	.773	.740	.667	.755							
9	.765	.733	.724	.783	.792						
11	.723	.613	.661	.599	.657	.644					
12	.775	.722	.760	.780	.759	.758	.682				
19	.756	.691	.670	.715	.710	.694	.600	.729			
31	.750	.715	.691	.745	.790	.766	.641	.741	.706		
36	.754	.660	.699	.689	.683	.661	.707	.694	.703	.672	

LINK 28. 1 LINKS TO 6 AT HOMOGENEITY LEVEL .79468

	1	2	3	8	9	11	12	19	31	36
2	.739									
3	.769	.706								
8	.776	.740	.683							
9	.770	.736	.721	.789						
11	.712	.618	.657	.657	.641					
12	.783	.716	.774	.753	.752	.675				
19	.757	.691	.674	.709	.693	.598	.727			
31	.760	.715	.683	.790	.763	.639	.737	.705		
36	.747	.658	.697	.681	.657	.704	.691	.700	.670	

LIN 2s. 8 LINKS TO 31 AT HOMOGENEITY LEVEL .7 363

	1	2	3	6	9	11	12	15	3E
2	.755								
3	.7 6	.7 2							
5	.7 6	. 5	.722						
9	.7e5	.73L	.715	.791					
1L	. 9	. 12	.655	.644	.635				
12	.7	. 2L	.7e9	.775	.751	.669			
19	.7^	. 4	.e7L	.711	.636	.5 4	.72		
36	.7+6	.654	.694	.675	.655	.7 1	.651	.697	

LINK 3 . 8 LINKS TO 9 AT HOMOGENEITY LEVEL .7.1.E

VERTICAL OF . [173 2 CLUST .If3.

	1	2	3	8	11	14	19	36
2	.752							
3	.764	.654						
6	.768	.7	.727					
11	. 3	.6	.694	. 37				
12	.777	.7 9	.7e1	.765	.665			
19	.75e	.6	.6t	.7E1	.5	.7.7		
36	.7 2	. 69	.695	.6 4	.698	. 7	.69e	

LINK 2.. 1 LINKS TO AT HOMOGENEITY LEVEL .77977

	1	2	3	11	12	.	36
2	.733						
3	.702	.639					
11	.71	.6 8	.644				
12	.77	.712	.753	.663			
19	.7 9	.675	.66	.6 9	.713		
36	.736	.644	.652	.693	.687	.6 5	

L14 36. 1 L1. 3 T. 12 AT HO. DOEHEIT LEVEL .77676

*	1	2	3	11	19	6
2	.73					
3	.702	.6 4				
11	.693	. 1	.64'			
19	.747	.66	.6 6	.6 6		
36	.733	. 41	.683	.6 6	.693	

L2'K 3 . 1 L1. 3 T AT HO' ENEIT' LEVEL .76204

	1	2	11	19	36
2	.72				
11	. 76	.684			
19	.72	.6 3	.673		
36	.715	.622	.687	.685	

L2 34. 1 L2' 3 TO 19 T 3 DO EITY LEVEL .72648

	1	2	11	36
2	.714			
11	.667	.575		
36	.715	.619	.677	

LINK 36. 1 LINKS TO 36 AT HOMOGENEITY LEVEL .70586

LINK 37. 1 LINKS TO 11 AT HOMOGENEITY LEVEL .67716

PECULIARITY INDICES FOR GROWING TREES.

SEQUENCE BY LIST OF ITEMS.

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38		
314	365	322	278	340	345	283	334	329	362	424	307	327	315	324	299	308	324	368	342
354	317	332	340	372	284	285	334	324	358	363	321	290	276	314	372	283	282		

SEQUENCE FROM SMALLEST PECULIARITY INDEX TO LARGEST.

36	6	31	30	26	37	38	7	1	12	17	2	14	33	23	32	9	29	15	18
19	13	22	3	25	20	24	5	27	8	35	16	31	19	36	10	2	11		
276	278	291	292	293	298	299	312	314	317	322	314	315	317	322	323	323	324	324	324
324	327	330	334	339	342	340	345	346	348	345	345	363	363	372	382	395	424		

19	-	10	.8426	325	347
18	-	12	.8329	306	307
10	-	5	.8205	341	340
17	-	9	.8334	287	342
16	-	22	.8250	299	312
15	-	5	.8314	317	320
4	-	1	.8166	278	303
1	-	5	.8020	295	324
20	-	8	.8116	336	340
1	-	6	.7947	320	347
8	-	31	.7836	334	351
9	-	3	.7914	323	343
1	-	6	.7798	321	340
12	-	4	.7783	316	324
3	-	1	.7820	312	321
1	-	19	.7265	321	360
1	-	38	.7854	323	372
1	-	2	.8321	324	396
1	-	11	.8102	326	404

PROCESSING COMPLETED.

DATE OF RUN .....

EXECUTION TIME .....

REMARKS/ERROR CODE ..

ITEMS AND CLUSTERS ARRANGED BY THEIR MEAN PECULIARITY INDICES.

3 38 37 26 21 12 4 7 1 10 32 29 35 33 28 36 17 23 15 14 1 19 24 25 30 5 27 21 20

9 8 8 31 18 36 2 11

LEADER AND MEAN PECULIARITY INDEX TABLE.

ITEMS IN CLUSTER	PECULIARITY LEVEL AT LINK	RESPECTIVE MEAN PECULIARITY INDICES	
32 - 38	.1270	323	324
7 - 1	.2221	203	204
29 - 35	.1252	332	329
21 - 24	.1259	336	342
31 - 18	.2254	280	293
4 - 40	.0167	348	351
34 - 33	.1652	332	340
22 - 27	.1121	317	324
37 - 31	.1130	320	323
10 - 26	.1752	329	336
39 - 11	.2911	276	283
20 - 28	.1750	292	272
12 - 20	.1714	327	327
8 - 23	.1126	286	280
14 - 16	.1527	315	315
16 - 2	.1153	341	341
17 - 40	.1972	302	329
10 - 30	.1498	340	351

ITEMS AND CLUSTERS SEQUENCED BY THEIR MEAN PECULIARITY INDICES.

3 36 37 29 26 12 4 7 1 16 22 [illegible] 32 33 35 28 34 17 23 15 14 [illegible] 18 24 25 30 5 27 21 20

6 9 8 31 19 [illegible] 2 11

LINKAGE AND MEAN PECULIARITY INDEX TABLE.

ITEMS OR CLUSTERS LEADING			HOMOGENEITY LEVEL AT LINK	RESPECTIVE MEAN PECULIARITY INDICES	
32	-	35	.3270	323	324
7	-	1	.3331	303	304
23	-	15	.3239	322	324
21	-	20	.1284	336	342
34	-	28	.3254	283	282
24	-	25	.3167	348	353
30	-	27	.3192	282	283
22	-	29	.3121	317	324
22	-	32	.3138	320	323
33	-	26	.2953	329	334
19	-	17	.3031	279	302
26	-	24	.2756	284	292
13	-	10	.2734	327	332
5	-	27	.2816	346	346
14	-	30	.2917	310	355
10	-	14	.2533	341	356
37	-	18	.2473	303	329
18	-	30	.2545	345	355